

Assessing the Level of Service for Shipments  
Originating or Terminating on Short Line Railroads

by

Steven M. Alpert

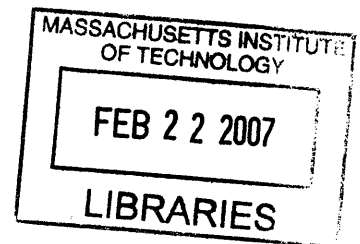
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Submitted to the Department of Civil and Environmental Engineering  
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## Abstract

This thesis measures railroad freight trip time and trip time reliability for freight rail shipments involving short lines in 2006. It is based on an underlying MIT study commissioned by members of the short line railroading industry, including the American Short Line Rail Road Association, and RaiLinc Corporation, a company that provides many railroad-related services. The data for this thesis is provided by several short lines through RaiLinc Corporation, which gathers and releases the data.

Data from a 90-day window is gathered for 39 shipping lanes spread amongst several short line railroads, with a total of 6,747 movements analyzed. In addition, two shipping lanes of 69 total movements that were provided for preliminary analysis are presented in greater detail. Two short lines have also provided their own multiyear data on car movements.

The significant result of this thesis is that there is an average time from shipper to customer of 8.3 days per load, with a standard deviation of 4.3 days. There is an average 2-day percentage, or highest percentage of loads to arrive in any 2-day window, of 44.7%. These numbers represent a moderate increase in trip time and trip time unreliability from the 1990-1991 numbers presented by a 1995 trip time study.

Thesis Supervisor: Carl D. Martland

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## Dedication

First and foremost, this thesis is dedicated to the four people at MIT who showed me that my passion for highways is really a passion for transportation. They were each able in their own way to get me to be deeply interested and much more well-versed in non-highway modes of transportation, including but not limited to railroads. In addition, all four have been instrumental in shaping my development from civil engineering student into transportation professional, and who have helped balance my highway love with an understanding of all facets of the transportation profession. I therefore dedicate this thesis to, in alphabetical order, Senior Research Associate Carl Martland, Senior Lecturer Fred Salvucci, Professor Joseph Sussman, and Professor Nigel Wilson.

I would further like to dedicate this thesis to the good friends who have helped me through the academic pressure of researching and writing a thesis. The first dedication is to David Grabiner, who not only lives a short walk from my apartment, but is always available to do anything non-academic when my week has been nothing but academic. The second dedication is to Kelly Wallenstein, who taught me that my true passion is not just for knowledge, but for life itself. She has also taught me that despite the changes in life, it goes on nonetheless, and I should always remain true to myself through it all.

Finally, I dedicate this thesis to all of my family and friends who have supported me. There are too many to list here, but what I appreciate about all of them is that they have been here telling me I can, in fact, write more than twice as many pages as ever before and keep it interesting. They have shared the highs and lows with me throughout all of this, and they deserve credit for that.



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## 1 Introduction

The purpose of this thesis is to assess the current trip times and trip time reliabilities for freight movements, and segments thereof, across the United States. By developing a picture of the current state of rail transportation, this thesis demonstrates how rail shipping times have trended from the past to the present, and shows areas for improvement upon those times in the future. To arrive at this picture, this thesis analyzes freight movements that each involve one or more short line railroads, as well as one or more Class I (major) railroads.

This thesis is based on a study commissioned by the Finger Lakes and Arkansas and Missouri Railroads, the American Short Line Rail Road Association (ASLRRA), and RaiLinc Corporation. These railroad personnel, through the administration of the ASLRRA, have commissioned MIT to study the issues and opportunities facing railroads, specifically in the area of merchandise freight, based on available data that reflects the state of railroading in 2006.

The ASLRRA is a trade organization that represents over 400 member short line and regional railroads. It advocates for measures that benefit short line railroads and railroading in general, in the context of improving the national freight economy. Concerning the MIT study and in the findings documented in this thesis, the interest of the ASLRRA is to understand the current state of railroading as a basis for continuing efforts to improve merchandise freight and the health of railroads.

The goal of this thesis is twofold. Based on data reported by individual railroads, the study aims to arrive at a general sense of the level of service provided by rail. By looking at the reports for several cars originating and terminating in the same places, average travel time and a measure of trip time reliability can be determined, and then compared to historical data or assessed in its own right. The other goal is to try to determine how service varies based on such

factors as time of year, day of the week, time of day, and geography, and in the long term, to assemble a picture of how service varies yearly, and whether there are noticeable long-term trends.

## 1.1 Need for Study

A better understanding of the level of service provided for freight railroad shippers is necessary to ensure the health of freight railroading. In particular, by analyzing loads whose transit involves short line railroads, this thesis will demonstrate why the origin-destination performance of those loads needs stabilization. To underscore the importance of the health of short line railroads, in recent studies, 30% (2006 data from RaiLinc) or 31%<sup>1</sup> of all carloads were found to involve short lines. That number may be even higher due to occasions of Class I railroads reporting events (such as arrival at a city or at the destination) that may have actually occurred on a short line.

One of the goals of the short line railroads funding the MIT study is to improve car utilization based on the results of the study. This thesis helps toward the achievement of that goal by identifying where cars generally experience the greatest delay. Using that data, short lines and Class I railroads both can improve operating procedures and reduce car cycle time, thus allowing each car to be loaded more frequently. By identifying the sources of trip time variability, to help minimize that variability, trains can run closer to schedule, which improves daily operations and thus may allow more trains on the network each day.

The short line railroads involved also want to examine good and bad railroading practices uncovered during the MIT trip time study. One particular interest is in the characteristics of short-distance (under 500 miles) hauls. Another interest is in the relationship between Class I

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<sup>1</sup> [Bitzan, 2003]

railroads, who deal directly with customers, and short line railroads, who are viewed as connecting customers to the Class I railroads, and whether a direct relationship between short lines and customers might better serve those customers<sup>2</sup>.

## 1.2 Details of MIT Study for ASLRRA

Initial railroad data was provided by two short line railroads participating in the MIT study. The multi-year data provided enabled a preliminary study of railroad trip time and trip time reliability trends along each of the railroads on timescales of days, months, or years.

In addition to the analysis of this initial data, there was a meeting at the Finger Lakes Railroad in Geneva on 11/30/05 for observation of short line operations. During this visit, topics for research were generated, including the potential to analyze overall rail service level by categories. The basic structure of the MIT study was outlined as an analysis of rail service with the ability to break service down into categories, and its target audience (railroads, railroad customers, government, and communities) was identified.

In February 2006, the parties commissioning and conducting the MIT study met in Cary, North Carolina, at the headquarters of RaiLinc, a corporation that collects data from participating railroads, processes the data, and redistributes it to them, among many other rail-related functions. RaiLinc gathers car location data, including date, time, waybill date, destination, train, and other data elements. Some of this data is gathered electronically at trackside as each car passes a sensor, while some is provided by the railroads.

Those parties determined procedures for obtaining approximately 40 short line “lanes,” or origin-destination pairs. The parties cooperated in securing data-sharing agreements from several railroads, comprising a total of 42 origin-destination pairs, whose data were then sent to

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<sup>2</sup> [Finger Lakes, 2005]

MIT for the study. As part of those agreements, this thesis cannot identify the participating short lines; the privacy of the two short line railroads who provided initial data will also be maintained.

## 2 Background

This thesis deals with the issues affecting shipments that involve short line railroads. In the context of this report, short line railroads refer to Class III railroads, which have assets of \$22.2 million or less. There are seven Class I railroads (with assets of greater than \$277.7 million) with 99,000 miles of track, and 510 Class III railroads with 26,000 miles of track<sup>3 4</sup>. As mentioned in Section 1.1, approximately 1/3 of all railroad freight movements involve at least one short line railroad, which are usually limited to a small geographic area within one or two states.

### 2.1 Recent Railroad Trends

Due to rail freight shipping levels approaching the capacity of the railroad network, service quality is declining, as measured by increasing congestion and lower on-time performance<sup>5</sup>. At the same time, railroads are raising prices despite the declining service levels<sup>5</sup>, due to that capacity issue. Even as Class I railroads attempt to deal with chokepoints that restrict capacity, many short line railroads operate under capacity and have room to develop their customer base.

After the Staggers Act of 1980 removed most Federal regulation of the railroad industry, Class I railroads began to sell or abandon large portions of their networks. Those lines most at risk of being abandoned were low traffic branch lines and redundant trunk lines. Short line railroad corporations were able to profitably operate many of those local branch lines, but many were abandoned, and most parallel and doubled tracks were removed. By 2005, abandonments in most states have subsided, as documented by their state rail plans (see Section 2.2.4). In

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<sup>3</sup> [AAR, 2004]

<sup>4</sup> [AAR, 2005]

<sup>5</sup> [CURE, 2006]

addition, from 1999 to 2004, Class I railroads only removed about 2% of their trackage, versus 10% between 1994 and 1999<sup>6</sup>.

There is another problem facing short line railroads now: Class I railroads have adopted a standard of cars weighing a gross 286,000 pounds, or “286K cars.” Furthermore, Class I railroads, with the heaviest and highest-grade rail, can upgrade to 300K or even 315K cars. Many short line railroads have upgraded to 286K-capable rail, but as documented by state rail plans, others have limits of 263K cars or even only 200K cars, and heavy cars must be hauled at no more than 5 MPH on many short line miles.

This push for a heavier standard by Class I railroads threatens the short line railroad industry, as those lines with low profit margins cannot fund the necessary improvements to rails, track beds, and bridges to handle cars weighing 300,000 pounds or more. Also, since many 200K and 263K cars remain in service, as standards continue to increase, the utility of those cars decreases, and a lot of existing equipment ends up in disuse despite being in serviceable condition.

Because some short lines are not even able to upgrade to 286K-car standards with their own finances, while others choose not to do so, other sources of funding are necessary to bring all track up to higher standards. Under the new comprehensive Federal transportation act, SAFETEA-LU, there is \$7 billion available for short lines to upgrade their railroads under the Railroad Rehabilitation and Improvement Financing program<sup>7</sup>. Upgrading may be necessary to preserve the 31% (as cited in Section 1.1) of customers who access the national railroad network via short lines.

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<sup>6</sup> [AAR, 2005]

<sup>7</sup> [FRA, 2006]

## 2.2 Literature Review

The MIT study is the first in many years to analyze actual trip times and produce a picture of the state of the rail network. Studies commissioned by the AAR in the 1970's and 1980's also used trip time data to study how to improve trip time reliability, level of service, or a similar metric. A 1995 MIT study was performed on origin-destination trip times and trip time reliability, and is the most direct predecessor to the current MIT study for the ASLRRA.

### 2.2.1 1977 Trip Time Case Studies

The 1977 AAR report on railroad reliability<sup>8</sup> contains early figures on trip times and trip time reliability, and details the factors that may influence trip times. In this report, car utilization is cited as a concern among railroads, and service reliability (measured by trip time variability) is mentioned as the key to better performance and an improved level of service. Other needs mentioned in the report are an improved focus on empty car handling and a system perspective of maximizing total performance instead of concentrating on each train.

Through case studies, this report shows how identified solutions helped network performance upon implementation. Reducing the number of yards visited per trip and entering into interline agreements to cut off circuitous routes both result in decreased trip times and increase trip time reliability. Among many other cited ways to improve reliability are run-through trains that do not stop in yards, closer schedule adherence, more locomotive power, signal and right-of-way improvements, and new operations control systems and procedures. These recommendations are still relevant to improving railroad trip times and trip time reliability.

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<sup>8</sup> [AAR, 1977]

Three of the studies in this AAR report detail shipping times by particular customers on three different railroads. Among the total of 63 origin-desination pairs and 9,562 shipments analyzed, there is an average of 6.5 days shipping time, and the average 2-day percentage is 53%. The 2-day percentage represents the highest percentage of shipments to arrive along a given origin-destination pair in any possible 48-hour window.

### 2.2.2 1978 Fleet Performance Study

The 1978 AAR railroad operations<sup>9</sup> involves a simulation of railroad car fleet performance based on shipper and railroad variables such as empty car availability, rate of goods production, trip time and trip time variance, backlogged goods, and stockouts at the eventual customer. The report studies whether the reduction of fleet size can improve railroad performance, and finds that capacity can be increased without adding cars to the fleet, if trip time reliability is improved.

The best general capacity-building solution, according to the report, is to work on strategies to improve trip time and trip time reliability, which is the focus of this thesis. Faster loading and unloading of goods also improves capacity by reducing the time cars were not in transit. In fact, capacity is most improved by reducing fleet size while improving car cycle time, since excess cars are removed from the rails thus improving fleet utilization. For more detail on how various reductions in fleet size affect performance, including the need to provide for stockouts or to bolster the fleet with non-assigned cars during peak periods, see the report itself.

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<sup>9</sup> [AAR, 1978]



### 2.2.3 1995 Origin-Destination Trip Times and Reliability Study

In 1995, MIT prepared a report on freight railroad trip times and trip time reliability for the 74<sup>th</sup> annual TRB Meeting in Washington, D.C.<sup>10</sup>. This paper reviews data gathered by the Association of American Railroads for trips between various origin and destination pairs from 1990 to 1991. The sample used for these trips is 10% of all trips made by certain car types, and the study is broken down by general merchandise, unit trains, and double-stack corridors.

The relevant finding of the Kwon et al. report is that the average loaded general merchandise trip time is 8.8 days, with a 2-day percentage of 48.6%. For interline (involving more than one carrier) railroad movements, the only type considered in the studies for this thesis, the average loaded trip time is 9.8 days.

Another result presented in this report is that for the highest-volume lanes, the average loaded trip time was only 7.2 days in 1990-1991. This is relevant because the data selected for the MIT study that underlies this thesis was gathered with the intent of capturing high-volume lanes (200 or more cars per year).

Other findings in the study include that 2-day percentage (see Section 2.2.1 for definition) is shown to vary widely across different railroad moves, with a range of 10% to 100%. Unit trains and double-stack trains are found to have arrived more consistently than other trains, with a 2-day percentage of nearly 90%.

### 2.2.4 Rail Plan Survey

A review of state rail plans was done to determine what issues may be pertinent to short lines across the country, and is included here to frame the importance of the findings of this thesis. In a preliminary examination of the state of railroading in 2005, a thorough Internet

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<sup>10</sup> [Kwon et al., 2005]

search for state rail plans yielded twenty states that provide standalone rail plans online. Websites of Metropolitan Planning Organizations (MPOs), state rail associations, and the ASLRRA were also surveyed for information. All of these websites are cited in the bibliography for this thesis.

The issues common to the state rail plans reflect a variety of interests, including those of railroads, rail shippers and consumers, communities adjacent to railroads, travelers crossing railroads, and neighboring states. While the short line representatives in the group commissioning the MIT study (on which this thesis is based) have identified their own set of issues, the issues mentioned within state rail plans also affect the future of short line railroads and railroading in general. The level of service conclusions of this thesis can be framed by the need to maintain or improve customer service while addressing pertinent issues.

Table 2-1 on the next page summarizes the commonality of elements discussed within the twenty surveyed rail plans and on the ASLRRA website. The ASLRRA identifies and is concerned with most of the same issues as state rail plans, where relevant, although some state-focused measures such as the need for state funding of railroad improvements are not addressed by the national organization.

Table 2-1. Elements Common to State Rail Plans and ASLRRA

Element	# of Plans Discussing	ASLRRA Discusses?
Intermodal facilities	19	•
Available funding sources	18	•
Grade crossing safety	18	•
286K car and infrastructure issues	17	•
Abandonments, low-density lines	17	•
List of short lines in state	17	N/A
State origin/destination study	16	N/A
Business, industry, the economy	15	•
Call to preserve abandonments (rail banking)	12	•
Traffic density study by line	12	N/A
Capacity: using excess or needing more	11	•
Competition by trucks and other modes	11	•
Need for funding (general)	11	•
Need for funding by state/states	10	
Setting out goals of rail plan	9	N/A
Environment and community effects	8	•
State acquisition or ownership of rail	8	
Dedicated short line section in plan*	6	N/A
Equipment issues	6	•
Security/STRACNET†	6	•
Specific history of funding allocations	6	N/A
Access and mobility	5	•
Future traffic growth	5	
Operating speeds and rail weights	5	
History of short line expenditures	4	N/A
Labor issues	1	•

Some elements such as infrastructure and safety issues are nearly universal in rail plans, but still do not appear in all of them. One commonly cited fact, within the issue of infrastructure and upgrading to 286K cars (cars with a gross maximum weight of 286,000 pounds), is that if short lines cannot afford to upgrade their infrastructure and shippers switch to trucks, a large amount of added highway maintenance and other costs would accrue on publicly funded roads. In Kansas, for example, the death of all short lines in the western half of the state would result in

an additional \$50 million per year of pavement damage<sup>11</sup>, on roads in counties that could not fund that extra amount.

Certain rail plans identify unique elements, or addressed unique issues, compared to the others. California<sup>12</sup> details new technologies and their impact on railroading. Georgia<sup>13</sup> studies their own and other states' funding allocations to railroads in some detail, and breaks down funding needs for each short line railroad. Oregon<sup>14</sup> shows shipper rankings of railroads in several categories, in a comprehensive shipper survey. Pennsylvania<sup>15</sup> examines flow across the state and identifies rail choke points, calling for a special task force to study how to accommodate the predicted rise in freight congestion.

Finally, Virginia<sup>16</sup> forecasts freight movement by mode in the future (2010-2025), including expenditures and funding priorities, under three different scenarios: status quo, strategic investments, and a fully integrated system involving large-scale and multi-state initiatives. There are also projections on population and employment growth, and how those trends affect freight demand across modes, and projections of annual rail needs, separated by lines and projects, until the year 2025.

### 2.3 Details of Issues Facing Short Lines

This section elaborates on some of the more important issues facing short line railroads, as found in state rail plans and on the ASLRRA website. See Table 2-1 above for a more

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<sup>11</sup> [Babcock/Sanderson, 2004]

<sup>12</sup> [CalTrans, 2002]

<sup>13</sup> [Georgia DOT, 2000]

<sup>14</sup> [Oregon DOT, 2001]

<sup>15</sup> [PennDOT, 2003]

<sup>16</sup> [Virginia Dept. of Rail and Public Transportation, 2004]

comprehensive list of issues, albeit a more general list. The issues directly cited by the group funding the study underlying this thesis are mentioned in Section 1.1 (“Need for Study”) above.

The ASLRRA notes that truck rates tend to be much higher than rail rates, but rail is too sparse to capture a lot of customers. They observe a Class I practice of bypassing short lines whenever possible, even when short lines are more direct or when truck connections are required instead of an all-rail route. The ASLRRA believes that the combination of these two facts has kept rail from achieving a more competitive market position<sup>17</sup>.

An issue nearly universal to state rail plans is upgrading track to handle 286K cars, which have a gross laden weight of 286,000 pounds as contrasted with the previous 263,000 pound standard. The new standard was promoted by Class I railroads in order to consolidate material into fewer cars over long hauls. Class II and III railroads, however, have significant stretches of railroad that cannot handle that standard. In 2004, more short line rail miles were of a 90-112 lb./foot weight than higher than 112 lb., resulting in the fact that 45% of short line miles are known to be unable to handle the heavier cars, compared to 39% that are known to be capable<sup>18</sup>.

One major issue identified directly by short line railroads is equipment utilization, a topic only covered in six of the twenty state rail plans surveyed prior to this thesis. As short line railroads define the issue, upgrading rail to meet the 286K-car standard is only one option. In the perception of one railroad, there is a need to better use the equipment they already have, such as permanently coupling two lower-capacity (such as 200,000 pounds) cars together and treating them as a single car<sup>19</sup>. Even though, per car, loaded trips are growing faster than empty trips<sup>18</sup>, empty trips still represented about 40% of total trips as of 2001. In fact, in the 2005 “Railroad

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<sup>17</sup> [Turner/Timmons, 2005]

<sup>18</sup> [AAR, 2004]

<sup>19</sup> [Finger Lakes interview]

Facts,” empty miles are shown to be increasing, while loaded miles are decreasing; thus empty car handling is an important issue in the analysis of equipment utilization.

Abandonment is also identified by many state rail plans as an issue, although in most states the trend is slowing. This spate of abandonments was sparked by the Staggers Act of 1980, which largely deregulated the rail industry, as well as prior acts in the 1970’s that streamlined the abandonment process under the ICC. Deregulation allowed Class I railroads to reduce or discontinue service on low density and unprofitable lines; many of these lines were sold to short line railroad companies, while others were abandoned. Some short lines later abandoned their lowest-profit or redundant branches as well, continuing the trend of abandonments into the mid-1990’s before the rail system started to stabilize. As Class I railroads start to face capacity issues in the first decade of the 21<sup>st</sup> century, new lines and reuse of formerly abandoned lines are coming to balance the disuse of other track.

### 3 Methodology

The methodology will describe how the main data set for the study underlying this thesis was chosen, and how the other data sets presented in this thesis were obtained. It will then detail how each data set was manipulated and what results have been obtained from each, relevant to this thesis's purpose of analyzing trip times and trip time variability.

#### 3.1 Choice of Main Data Set for MIT Study

As mentioned in the introduction, the parties responsible for the MIT study underlying this thesis include Finger Lakes and Arkansas and Missouri Railroads, the American Short Line Rail Road Association (ASLRRA), and RaiLinc Corporation. Through conference calls, Internet communication, and preliminary meetings, these parties determined that 40 lanes of reasonable size should be selected, striking a balance between not having enough data points to analyze effectively, and having too many to analyze in a reasonable amount of time.

On February 22<sup>nd</sup>, 2006, the presidents of the Finger Lakes and Arkansas and Missouri Railroads met in Cary, North Carolina, at the headquarters of RaiLinc Corporation. Representatives from MIT, RaiLinc, and the ASLRRA were also present at the meeting. One topic of that meeting was the logistics of finding short lines to participate in the study; other short lines with potential interest in providing data were identified and invited to participate in the study.

Also discussed was criteria for lane selection. Because the length of rail haul is not specified for each available lane, the proposed analysis of hauls by length (e.g. less than 500 miles, between 500 and 1,000 miles, etc.) cannot be easily done directly from the RaiLinc data.

Thus the main criterion for selecting lanes was to obtain a geographic spread, in order to represent data from across the country.

At this meeting it was determined that approximately 45 movements would be sought, allowing for data reporting errors in a few of the lanes. These lanes would be drawn from short lines across the country, thus representing a cross-section of all regions and minimizing geographic bias.

### 3.1.1 Main Data Set Compilation

Six initial lanes, where each lane is defined by origin and destination, were identified as a pilot program in order to determine what studies could be performed on the available data. While only two of those lanes were positively identifiable, those two are studied in great detail. In this thesis, they are presented separately from the main data set ultimately provided, and are identified throughout this thesis as Lane 1 and Lane 2.

The problem with identifying four of the original six pilot lanes was that the origin and/or destination, as specified by the short line releasing the data for the study, did not match the origin or destination given in the RaiLinc database. The method of data acquisition was then refined so that short lines would provide a sample waybill number or other identifying data to RaiLinc in order to conclusively determine the origin/destination pair being studied.

Ultimately, RaiLinc provided data from 42 lanes, over a 90-day history<sup>20</sup> for each lane. In the 42-lane data set, one of the lanes only has one car reported in the sample, and thus it is excluded from the study due to insufficient sampling. Two other lanes are incorrectly specified, meaning that a range of destinations were reported for cars coming from a single origin, and the

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<sup>20</sup> 90 days is the maximum archive kept in active storage by RaiLinc; historical archives are stored separately, and are difficult and costly to access.



specified destination is not present in that range. This leaves 39 lanes in the main data set, which was deemed by the group to be close enough to the target of 40 to proceed.

Table 3-1. Railroad Event Definitions

Release	Shipper notifies originating railroad that load is ready for pickup
Pull	Originating railroad takes load from shipper siding, warehouse, etc.
Junction delivery	Railroad delivers car to be shipped on another railroad's train
Junction receipt	Railroad accepts car delivered by the previous railroad's train
Destination arrival	Car arrives at the location of the customer
Constructive place	Terminating railroad offers car for delivery to customer; customer does not accept
Actual place	Customer accepts car for delivery to customer siding, warehouse, etc.
General place	Constructive place (CP) when reported, and actual place when CP is not reported

Table 3-1 defines railroad terminology as it pertains to this thesis. The events listed in the left column are all present in the data provided by RaiLinc for the MIT study, except general place which is a combination of two events. Depending on the railroads carrying each particular car, some of the lanes do not report many of those events. Those reporting errors are discussed in Section 3.4.

The measures of trip time and trip time reliability used in this thesis depend on the times between certain key events present in Table 3-1. The overall trip is defined as release to general place. Where applicable, time on originating short line is measured from release to junction delivery, and time on terminating short line from junction receipt to general place. Also, wherever results are presented that involve general place, the same results are presented with data to constructive and actual place. Time between constructive and actual place is another benchmark for data analysis in this thesis.

### 3.2 Other Data Sets

Two short lines have provided additional data on rail service. The first railroad, to be referred to as Railroad “A,” provided data for all incoming car movements on one of its two connecting Class I railroads between 2000 and 2005, with partial data for 1999. The data contains origins from across the country, and its only bias is that all movements contained within the data utilize the same Class I railroad. Also provided is a summary spreadsheet organized by originating state and city, with number of carloads and average trip time given both by month and cumulatively for the year.

The other railroad, to be referred to as Railroad “B,” provided data on six different routes terminating on that particular short line. The six moves in the set from Railroad “B” were selected to provide a representative sample of all of the moves involving that short line, and thus may exhibit slight selection bias. Included in the data are measures such as waybill date, date received by Railroad “B,” and date delivered empty by Railroad “B” after having been unloaded by the customer.

### 3.3 Data Set Analysis

#### 3.3.1 Analysis of MIT Study Data

RaiLinc sent the main data in the form of 42 Excel spreadsheets, whose columns include car identification number, waybill number, destination, and the location, date, and time of each event. As previously mentioned, two spreadsheets do not include the specified destination, and one only contains one car movement. Also, one spreadsheet provided has less data and is in a unique format; since it only contains ten movements, it could be analyzed separately by hand.

First, each spreadsheet had to be converted into uniform formats in order to facilitate the application of Excel formulas. Some spreadsheets contained additional columns, many of which supplied redundant information, that are not relevant to this study. Those were deleted in order to more efficiently analyze the data within. Also, the spreadsheets reported date and time in one column as text, which had to be reformatted into date and time values in order to perform calculations on them.

Finally, a few spreadsheets listed events in alphabetical order instead of time order. Those are sorted by car number, event day, and event hour. Because the data analysis focuses on the timing of specific events such as load origination, junction delivery or receipt, and constructive or actual place, this method of sorting the data allows calculations to be performed based on specific events being in order.

After the data files were converted to the proper formats, they were then analyzed for data reporting errors, which are described in Section 3.3.4. The next process was to apply formulas within Excel to determine the number of hours between certain events in each data set, such as the time from release to constructive place (see Appendix A). The main categories of data collected from the lanes are times from release to actual place, release to constructive place, destination arrival to constructive place, and destination arrival to actual place. Other data includes time on short line and time in particular yards (those yards in which a yard short line handles the car).

After applying these formulas, each file was manually checked for anomalies, such as partial moves (moves that were cut off in the data set) that might yield erroneous values of shipping times. The appropriate values were deleted, or if the error appeared to be systematic, the relevant formulas were altered to account for it.

In the end, the move times for each lane can be combined to produce a mean trip time and standard deviation of said trip time. The standard deviation, or trip time reliability, is then combined with the mean trip time as a measure of overall trip performance, and the aggregate numbers are combined into 39-move mean measurements.

#### 3.3.1.1 Analysis of Lane 1 Data

The procedures described above in Section 3.3.1 are also performed on Lane 1. Lane 1 consists of 33 records for a single origin-destination pair, spanning the first three months of 2006. Each of the 33 records have been manually separated by railroad, and formulas are applied to determine trip times for each record.

The trip times obtainable from the Lane 1 data include time on the Class I railroad from release to short line junction, time from short line junction delivery to receipt, and times on the short line railroad between receipt, constructive place, and actual place. Based on the reported dates and times, the 33 records are sorted onto 20 Class I trains and 16 short line trains for analysis by train instead of simply by car. Means and standard deviations for all sections of the trip were obtained.

#### 3.3.1.2 Analysis of Lane 2 Data

Similarly to Lane 1, the procedures in Section 3.3.1 are performed on Lane 2. Lane 2 consists of 36 records for a single origin-destination pair, and those records are also drawn from the first three months of 2006. The same separation of records as performed on Lane 1 was performed on Lane 2.

In the case of Lane 2, obtainable trip times include originating short line to Class I junction, time on the Class I railroad between short line junctions, and time on the terminating short line. Based on the reported dates and times, the 36 records are sorted onto 14 originating trains, 12 Class I trains, and 10 terminating trains.

Means and standard deviations for all sections of the trip are obtained, and the results graphically plotted. As a visualization aid, best-fit distributions are fitted, including normal, composite normal, and Poisson. Due to the low number of records, these distributions may look different if more data were to be obtained over the course of months or years.

### 3.3.2 Analysis of Data Set “A”

The data from Railroad “A” includes information on what that railroad calls T-Days, or the number of days in transit to the short line from origin. Among charts created from this information are a monthly trend of average T-Days from 2000 into 2005, average number of T-Days by month, yearly average trip time reliability (measured by the standard deviation of T-Days that year), and the yearly trend in T-Days relative to the monthly average.

Since the data from Railroad “A” is organized by state, yearly data can be charted on a map of the United States. The two categories of data thus charted are the volume of traffic originating from each state and the average number of T-Days from that state to the short line. These charts show trends in those states that consistently originate a significant number of cars, as well as give a picture of how geography affects trip time.

Also, because Railroad “A” data is reported in detail similar to that of the RaiLinc data, individual sample cars are traced from origin to junction with short line, a useful way to watch how cars travel between yards and through yards, and where large factors of delay are

introduced. With nearly six years' worth of data, there are other possible analyses to be performed, which will be outlined in Sections 6.2 and 6.3.

### 3.3.3 Analysis of Data Set "B"

The data available from Railroad "B" is more limited than the data in the other sets, but includes waybill date, date received by the short line, and date interchanged back from the short line. Because of the limitations of this data, waybill date is taken as the date of origination, even though it may take several days from release (usually when the waybill is dated) to pickup from shipper.

These three data points allow measurement of overall shipment time from origin to short line and overall time spent on short line. Overall time spent on short line includes customer unload time, and possibly reload time depending on the customer and car. Because these data are provided from 2000 into 2006, yearly trends are charted for all six lanes provided by Railroad "B," for both shipment time and short line time.

The coefficient of variation is also charted for both measures, where coefficient of variation is defined as standard deviation of trip time divided by mean trip time. Higher coefficient of variation signifies higher trip time variability, and because it is unitless, it allows comparison of moves of different lengths. As a measure of trip time reliability, lower coefficients of variation reflect less variability and thus a higher level of service.

### 3.3.4 Main Data Set Error Correction

The railroad data that is gathered by RaiLinc includes a number of errors that must be corrected or accounted for in order to obtain results like those presented in this thesis. One

common error is two different railroads reporting the same event happening at different times, or a later event happening at an earlier time. In these cases, for consistency segmented trip times are recorded based on the time reported by the railroad of interest. For example, if the short line railroad delivers a car for junction at 12:00 PM, and the Class I railroad reports receiving it in junction at 11:00 AM, the junction time would be counted as 12:00 PM when analyzing the short line segment of the trip, and as 11:00 AM when analyzing the Class I segment of the trip. For the overall trip time, the discrepancy is ignored.

Another common error is reporting a blank event, or multiple events of the same type, where an event is a single letter representing the action taken at that time (i.e. arrival, departure, bad order release, etc.). Unlike in some of the preliminary data sets analyzed, there is no duplicate reporting of all events for a single car; in those preliminary data, every other row for some cars had to be manually deleted in order to analyze the move. However, the final data provided by RaiLinc includes a phenomenon of blank events (no event type reported), which would often occur between constructive and actual place, or after actual place. In analyzing movement times, formulas rely upon the time to actual place, and then reset upon the beginning of the next movement; therefore, in those data sets which included blank events, formulas have to be altered to account for them.

As for multiple events, some data sets report four or five consecutive constructive places (notifying the customer that a car is available for pickup) before an actual place (delivering the car directly to the customer). This may not be a reporting error, but rather may be the customer refusing constructive place one day, only to be offered the car again on subsequent days. In order to accurately measure shipment times involving constructive place, the first constructive place reported is considered to be the only one.

There are certain discrepancies in the data reporting among the 39 lanes, some of which hamper data manipulation. In one lane, the initial release is not reported, but pickup from shipper is treated as the initial release because that data point is consistently reported. In another lane, both release and pickup are not reported for several movements, in which cases the next data point (arrival at the adjacent town) is treated as the release.

Among discarded data points, lanes which report receipt by terminating line but not destination arrival are not included in the measures related to destination arrival. Lanes that report constructive place prior to destination arrival are not included in the summary of times between destination arrival and constructive place. The explanation of this error is that constructive place is reported when the cars are offered to the customer; some short lines may offer the cars upon receipt in junction from the connecting railroad, while most do not report it until arrival at destination.

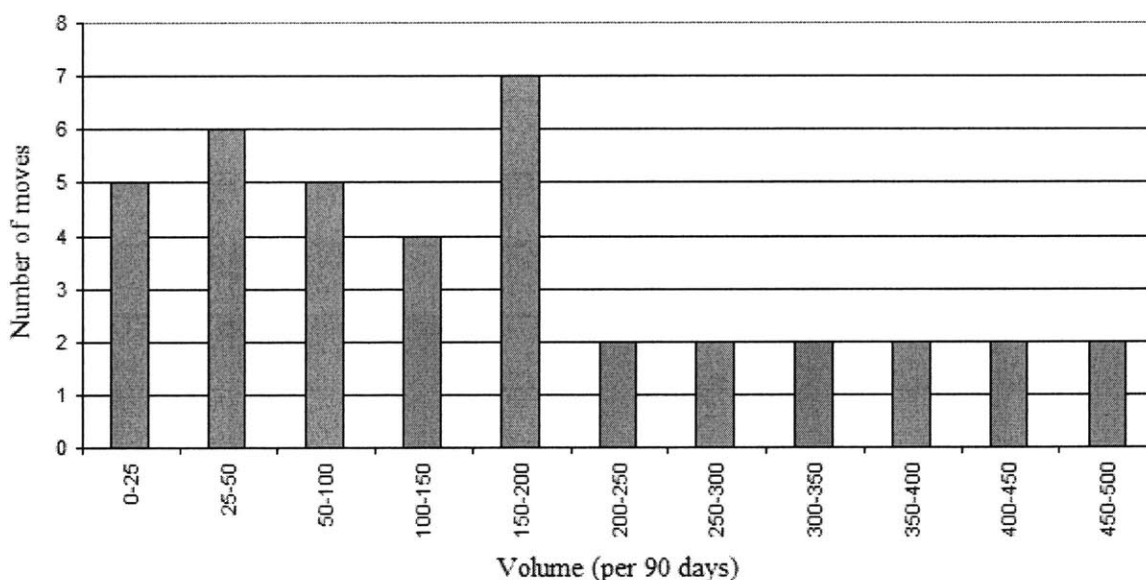


## 4 Results

### 4.1 Findings of MIT Study

Of the 42 origin-destination pairs for which data was provided, 39 are able to be used for this study, as discussed in Section 3.3.1. Those 39 pairs contain data for 6,747 complete car movements, as well as several other incomplete and unusable movements. The range of the number of usable car movements reported per origin-destination pair is from 6 to 569. As the goal of the underlying study is to identify lanes with 200 or more moves per year, the 11 lanes with fewer than 50 moves reported over 90 days may not fulfill that goal, especially the five with fewer than 25 moves reported.. Figure 4-1 shows the range of reported lane volumes.

**Figure 4-1. Volumes of 39 Lanes, Main Data Set, 90 Day Window**

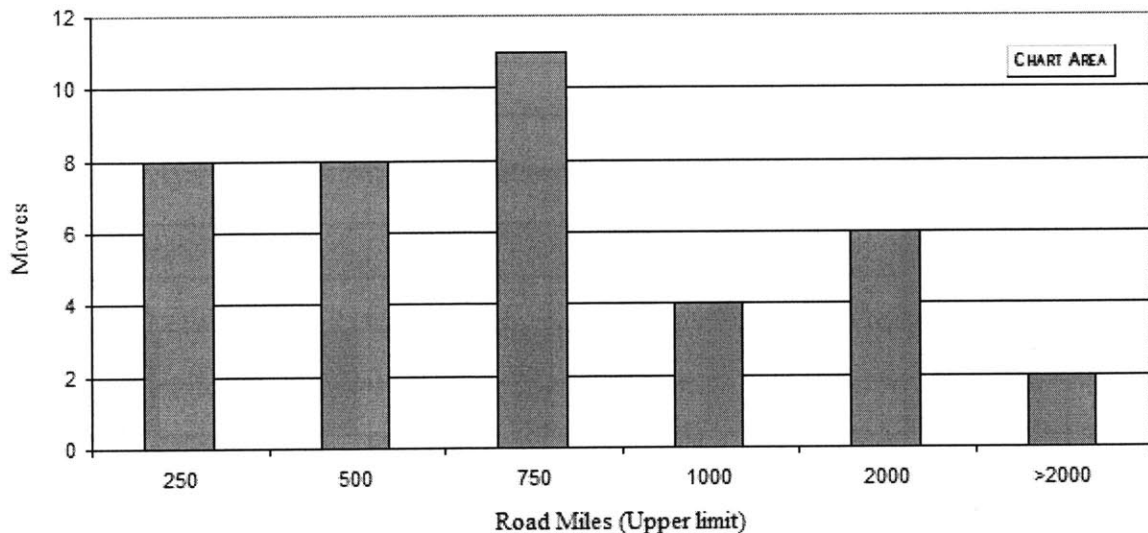


The 39 pairs studied also represent a range of distances for car movements. Using Google Maps to calculate road distances between origin and destination, and rounding to the nearest 5 miles due to imprecision in identifying those points, the observed range of distances is

from 80 to 2,380 road miles. These distances represent the approximate equivalent mileage the cargo would travel in trucks, as opposed to over rail, in order to afford a comparison of truck and rail mileage.

Eight of the movements considered in the study underlying this thesis are less than 250 miles, and a total of sixteen are less than 500 miles. There are also another eleven movements between 500 and 750 miles. The average road haul distance of the 39 lanes sampled is 455 miles when weighted by move volume, and 715 miles unweighted, meaning that in the sample, some shorter lanes have relatively high volumes. The range of movement distances is shown in Figure 4-2.

**Figure 4-2. Road Haul Distances of Lanes in Main Data Set**



The results available from the main data set include various general segment times: release to constructive place, release to actual place, destination arrival to constructive place, destination arrival to actual place. In addition, a measure known as general place is derived by using constructive place data where available, and otherwise using actual place.

Table 4-3 below shows the summary data for the 39 moves. The weighted average means are weighted by the volume of each lane, while weighted average standard deviations are actually the square roots of the weighted average variances, which are also weighted by the volume of each lane. The coefficient of variation (defined in Section 3.3.3) is a unitless measure of data spread, obtained by dividing the standard deviation for movements in each lane by the mean of that lane. The weighted average coefficient of variation is again weighted by the volume of each lane. Not reported below is median time from release to general place, which is just under 7 days.

Table 4-3. Trip Time and Trip Time Reliability, Main Data Set

	Avg. (hrs)		Avg. (days)		Range (hrs)
	weighted	unwghtd	weighted	unwghtd	
Time from customer release to actual place	227	274	9.5	11.4	79-614
Standard deviation for same	107	101	4.4	4.2	33-227
Coefficient of variation for same (no units)	0.36	0.33	N/A	N/A	.16-.71
Time from customer release to constructive place	160	196	6.7	8.2	70-363
Standard deviation for same	52	54	2.2	2.3	29-92
Coefficient of variation for same (no units)	0.33	0.28	N/A	N/A	.17-.59
<b>Time from customer release to general place**</b>	<b>200</b>	<b>224</b>	<b>8.3</b>	<b>9.3</b>	<b>70-614</b>
<b>Standard deviation for same</b>	<b>102</b>	<b>81</b>	<b>4.2</b>	<b>3.4</b>	<b>29-227</b>
<b>Coefficient of variation for same (no units)</b>	<b>0.38</b>	<b>0.31</b>	<b>N/A</b>	<b>N/A</b>	<b>.16-.71</b>
Time from destination arrival to actual place	39	54	1.6	2.3	0-272
Standard deviation for same	50	62	2.1	2.6	0-206
Coefficient of variation for same (no units)	1.18	1.12	N/A	N/A	0-5.45
Time from destination arrival to constructive place	12.9	14.3	0.5	0.6	0-34.1
Standard deviation for same	3.4	4.1	0.1	0.2	0-47
Coefficient of variation for same (no units)	0.88	1.09	N/A	N/A	.12-3.82
Time from constructive place to actual place	67	84	2.8	3.5	14-252
Standard deviation for same	78	80	3.3	3.3	8-204
Coefficient of variation for same (no units)	0.91	0.75	N/A	N/A	.33-1.34

The best measure of rail transit time is the time from release to general place. There is a weighted average of 8.3 days and unweighted average of 9.3 days from the time a load is released until it can be delivered to a customer. The standard deviations of 4.3 days weighted and 3.4 days unweighted reflect uncertainty in the system, with the respective coefficients of variation describing the level of uncertainty. The breadth of the range in arrival times, from 70 to 614 hours, also reflects system uncertainty.

Other important measures from this table are time from destination to constructive place and from constructive to actual place. The first measures how long it takes terminating railroads to offer loads to customers upon arrival, with an average of around half a day and standard deviations of 3-4 hours. The second measures how long it takes customers to accept the loads they are offered, an average of 3 days with a standard deviation of about 3 days as well. This measure contributes to car cycle time, although it is not technically part of the origin-destination trip time.

Another measure not reported in that table is the time between the last Class I yard and destination arrival on the terminating short line. This figure is only calculated for those lanes with a terminating short line. The last Class I yard is identified by manual inspection of the data to find in which location a Class I train consistently experiences arrival-departure times on the order of a day. Reported destination arrival is used where possible; otherwise, the last consistently reported location arrival before constructive or actual place is used.

The above analysis yields a time that does not contain yard delays, but does capture interchange delays. The time from yard to destination is a measure of the final leg of a car's trip. From the main data set, the weighted average time is 62.8 hours, and the unweighted average is

62.2 hours. The weighted average standard deviation is 45.1 hours, and the unweighted average standard deviation is 43.4 hours.

Based on the road distances and the observed average time per move, the average speed of each train movement was calculated in road miles per train hour (RMPH), as a comparison of rail and road shipping times. The average speed for all 39 movements, weighted by the volume of each movement, is observed to be 2.4 RMPH between release and general place. The unweighted average speed for all 39 movements is 3.3 RMPH between release and general place.

There appears to be a positive correlation between the effective speed of a train car and the distance it travels between origin and destination. Average equivalent car speed (AECS) can be defined as the relative speed of carloads if their trains were following truck routes over highways, with units of road miles per train hour. This positive correlation has a fairly high value of  $R=0.67$ , which is reflected in Figure 4-4 on the next page and will be explained in Section 5.1. Ignoring the effect of the number of yards involved in each move, it appears that the relation of AECS to haul length HL is approximately, in miles per hour:

$$\text{Equation 1: } \text{AECS} = 1.06 + .0031 \text{ HL}$$

The data can also be broken into trip segments for each lane. For each lane whose data includes the identity of the reporting railroad, it is possible to obtain the time spent on a particular railroad. This breakdown is performed for all identifiable short lines, including one case where no train is identified but the railroad is clearly performing a terminating function (receiving cars in junction and transferring them directly to the customer). The aggregate results are presented in Table 4-5, with the same weights (by volume of movements in each lane) as

above. In that table, total count refers to the number of cars being averaged, origination refers to short lines picking up cars from shippers and delivering them in interchange, and termination refers to short lines that receive cars in interchange and deliver them to customers.

**Figure 4-4. Correlation of Distance to Car Speed, Main Data Set**

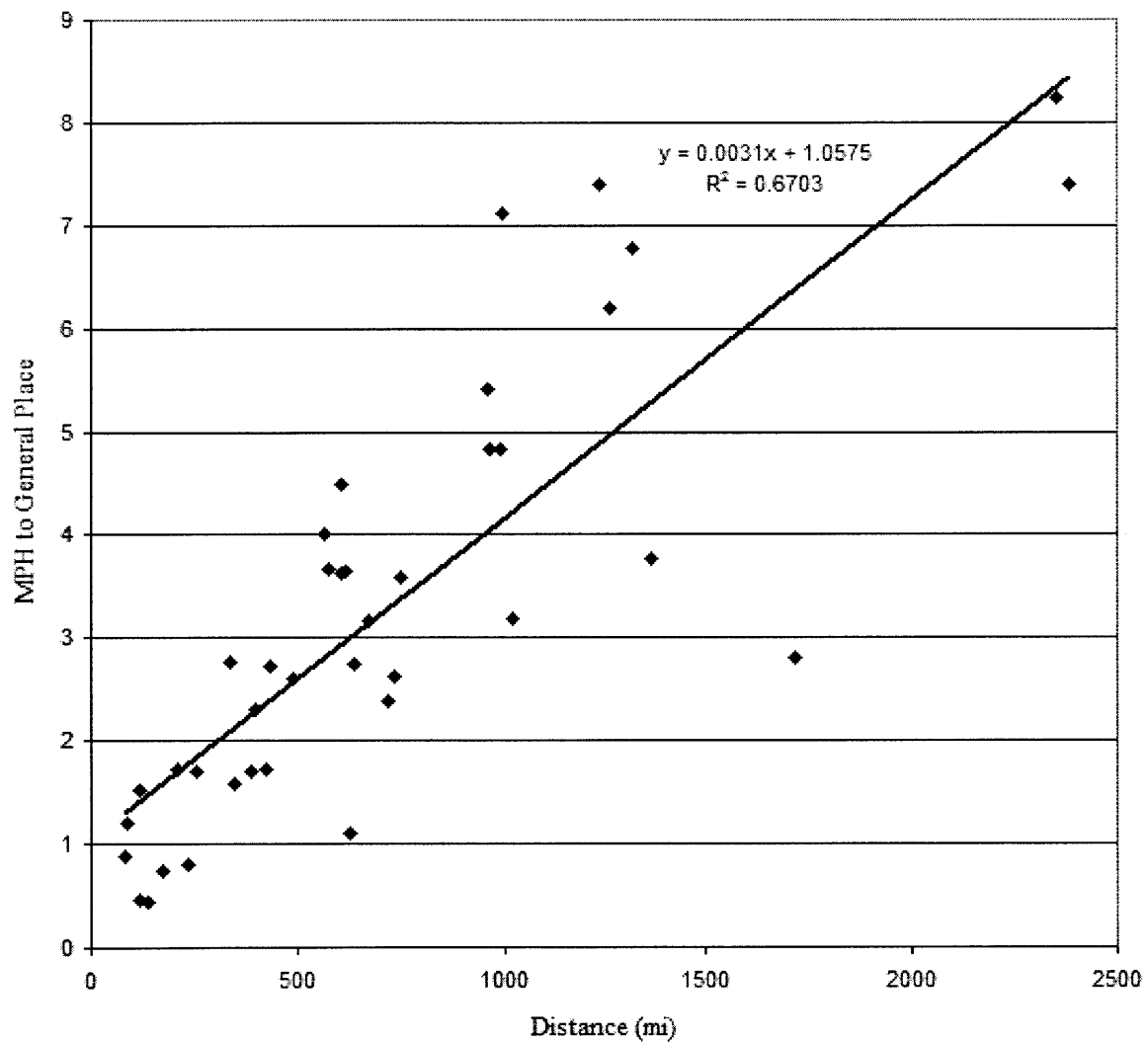


Table 4-5. Summary of Trip Segments from Main Data Set

TOTALS	Average (hours)		Standard deviation (hours)		Total count
	Weighted	Unweighted	Weighted	Unweighted	
Origination:	26.1	30.9	22.1	21.1	2147
Termination:	99.5	79.0	114.4	81.9	1688

Another measure that can be derived from the main data set is the 2-day percentage, as defined in Section 2.2.1. It would be statistically misleading to report the aggregate 2-day percentage for all cars in the main data set, because different lanes have different mean travel times, which would spread out the overall data more. As in the Kwon et al. study from 1995, there is a wide spread in the 2-day percentages across the 39 lanes in the study. The weighted average of the 2-day percentages for all 39 lanes in the study is 44.7%, while the unweighted average of the 2-day percentages for the 35 lanes with 20 moves or more<sup>21</sup> is 49.8%.

#### 4.1.1 MIT Study Special Cases

In the preliminary data sent by RaiLinc to determine what analyses could be done on the final set of lanes (the 39 lanes considered above), two of the six “trial runs” were clearly defined by origin and destination and could be studied in detail. A study performed with this level of detail is possible with much of the other RaiLinc data as well.

##### 4.1.1.1 Results of Lane 1 Analysis

Lane 1, described in Section 3.3.1.1, consists of a Class I railroad reporting events from pickup, junctioning a terminating short line that reports events to actual place. There is an

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<sup>21</sup> The reason the four lowest-volume moves are discarded is because there is a high degree of uncertainty associated with their statistics; this does not affect the weighted average, as these moves have corresponding low weights.

average, per train, of 21.5 hours between Class I junction delivery and short line junction receipt, with a standard deviation of 18.8 hours. Mean time on the Class I railroad, also per train, is 5 days and 4¾ hours, with a standard deviation of 22¼ hours. Other Lane 1 aggregate data, from time on the short line, is presented in Table 4-6 below.

Table 4-6. Hours Between Events on Terminating Short Line, Lane 1

	Mean	Standard Deviation
Junction receipt to destination arrival, hours	3.8	3.3
Destination arrival to actual place, hours	124	116
Constructive place to actual place, hours	108	121
Destination arrival to constructive place, hours	15.5	13.0
Junction receipt to constructive place, hours	19.3	12.2

There is one outlying data point from a weekend arrival included in the above table, the significance of which will be explained in Section 5.1.1.1. Excluding that one data point, there is an average of 12.4 hours (3.75 hour standard deviation) from destination arrival to constructive place, and an average of 16.3 hours (1.50 hour standard deviation) from junction receipt to constructive place.

#### 4.1.1.2 Results of Lane 2 Analysis

Lane 2, described in Section 3.3.1.2, consists of an originating short line delivering cars to junction with a Class I railroad, which then delivers cars to junction with a terminating short line. There is an average, per train, of 23.5 hours in transit on the originating short line, with a standard deviation of 7.6 hours. There is one outlying data point, on a train that takes 48¾ hours to travel from shipper to the Class I junction; without that data point, there is an average of 21.5



hours per train, with a standard deviation of 2.3 hours. The outlier will be explained in Section 5.1.1.2.

On the Class I railroad, there is an average mean haul time between short lines of 7.59 days, with a standard deviation of 2.16 days. Between junction receipt from the originating short line and departure from that junction, trains average 60.3 hours with a 35.3 hour standard deviation.

Finally, on the terminating short line there is an average, per train, of 5.9 hours in transit, with a standard deviation of 8.4 hours. There is an outlying data point here as well, on a train that took 28.4 hours from junction receipt to actual place, albeit only one hour from junction receipt to constructive place. Without that outlier, the average time spent on the terminating short line, per train, is 3.4 hours with a 3.0 hour standard deviation. Again, the outlier will be explained in Section 5.1.1.2.

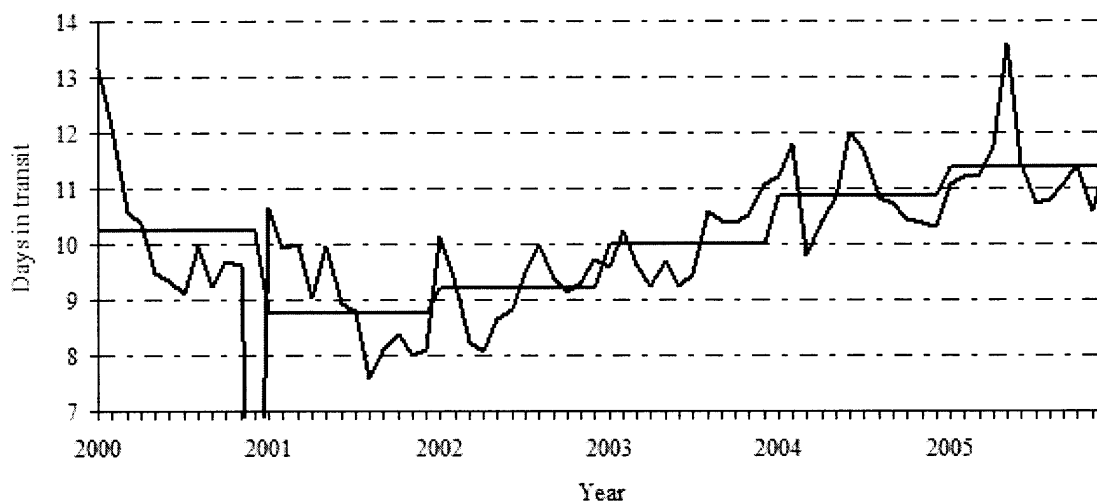
## 4.2 Findings from Railroad “A” Data

The data from the short line Railroad “A,” as described in Section 3.3.2, consists of detailed event data for all moves terminating on Railroad “A” delivered by a particular Class I railroad. As a reminder, the average transit time is presented as T-Days, or number of days in transit from origin to junction with Railroad “A.”

The average of T-Days across all moves present in the data drops from 10.2 days in 2000 to 8.8 days in 2001, then rises steadily to 11.4 days in 2005. Figure 4-7 on the next page shows the multiyear monthly trend in T-Days, plotted against the yearly average from 2000 to 2005. The data also yield the average trend of T-Days by month, which rises to 11 days in January from an average of approximately 10 days between March and November. Normalizing the

monthly T-Day data to this average monthly trend shows the same trend as in Figure 4-7 – namely, that T-Days decrease from 2000 to 2001, and then increase through 2005.

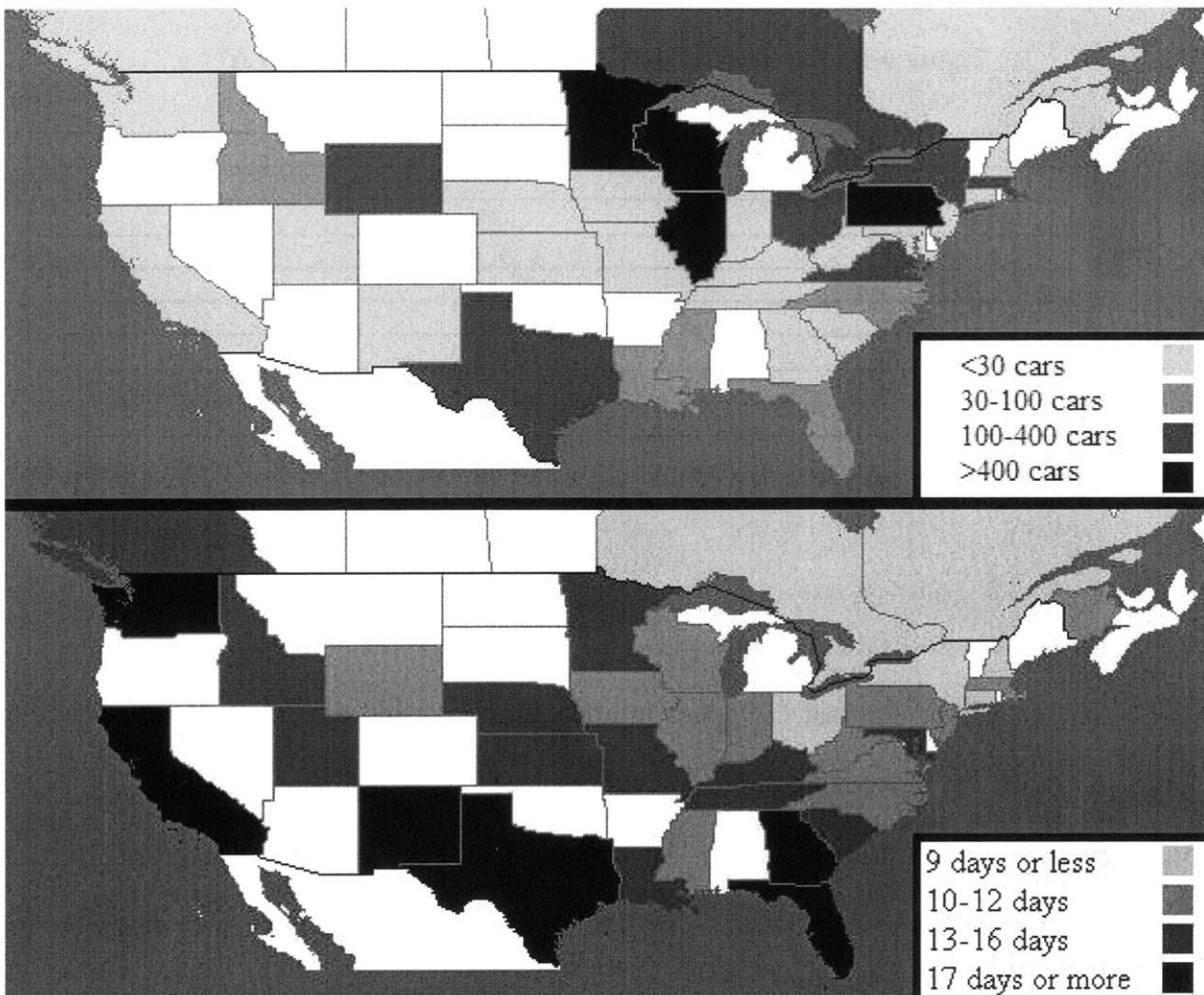
**Figure 4-7. Trip Times to Railroad "A," 2000-2005**



The Railroad "A" data also includes geographical information on load origins, allowing a graphical representation of shipment trip time and trip time variability based on origin. An example of such representation is shown in Figure 4-8 on the next page, where the short line in question is located in the northeastern United States.

The longest shipping times generally occur from the West and South, with the shortest shipping times clustered in the Northeast near Railroad "A." High-volume moves, such as cars coming from Illinois to Railroad "A," tend to have lower overall shipping times than some of the lowest-volume moves, such as the cars coming from California. Figure 4-8 represents T-Days for shipments in 2005; the yearly trend from 2000-2005 shows general consistency in which states yield long or short shipping times.

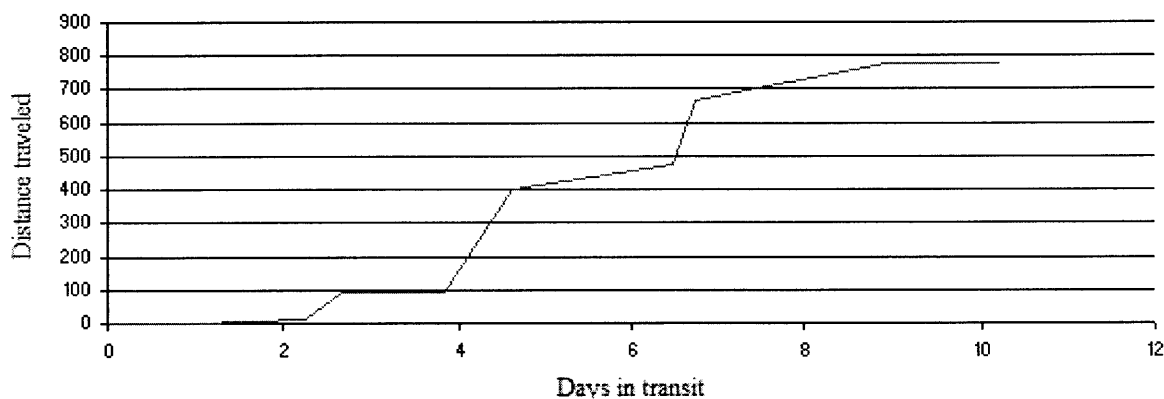
Figure 4-8. Volume and Transit Times to Railroad “A” by Origin



One other result obtained from Railroad “A” data is a detailed breakdown of the time it takes an individual car to proceed from shipper release to short line junction delivery. Such a breakdown can also be done with the main data set; Figure 4-9 below is a sample that demonstrates the difference between the average car speed (AECS from Equation 1) and the actual speed the car is traveling at any given time. Overall haul speeds (see Figure 4-4 and preceding discussion) include several stops at yards, where cars are switched between trains, and

at interchanges between railroads. Figure 4-9 shows that while a car may be in a yard for more than 24 hours, it can then move over 300 miles in just over 10 hours.

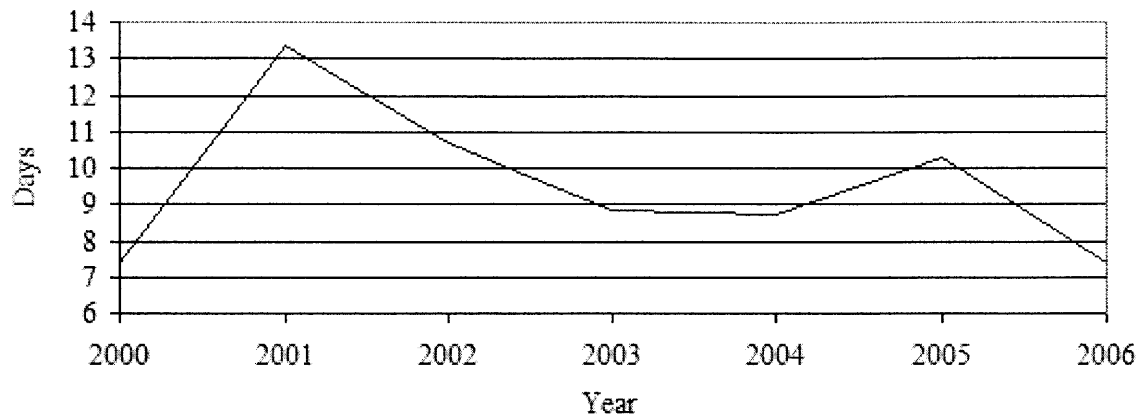
**Figure 4-9. Car Traversing Class I Railroad to Railroad "A"**



#### 4.3 Findings from Railroad "B" Data

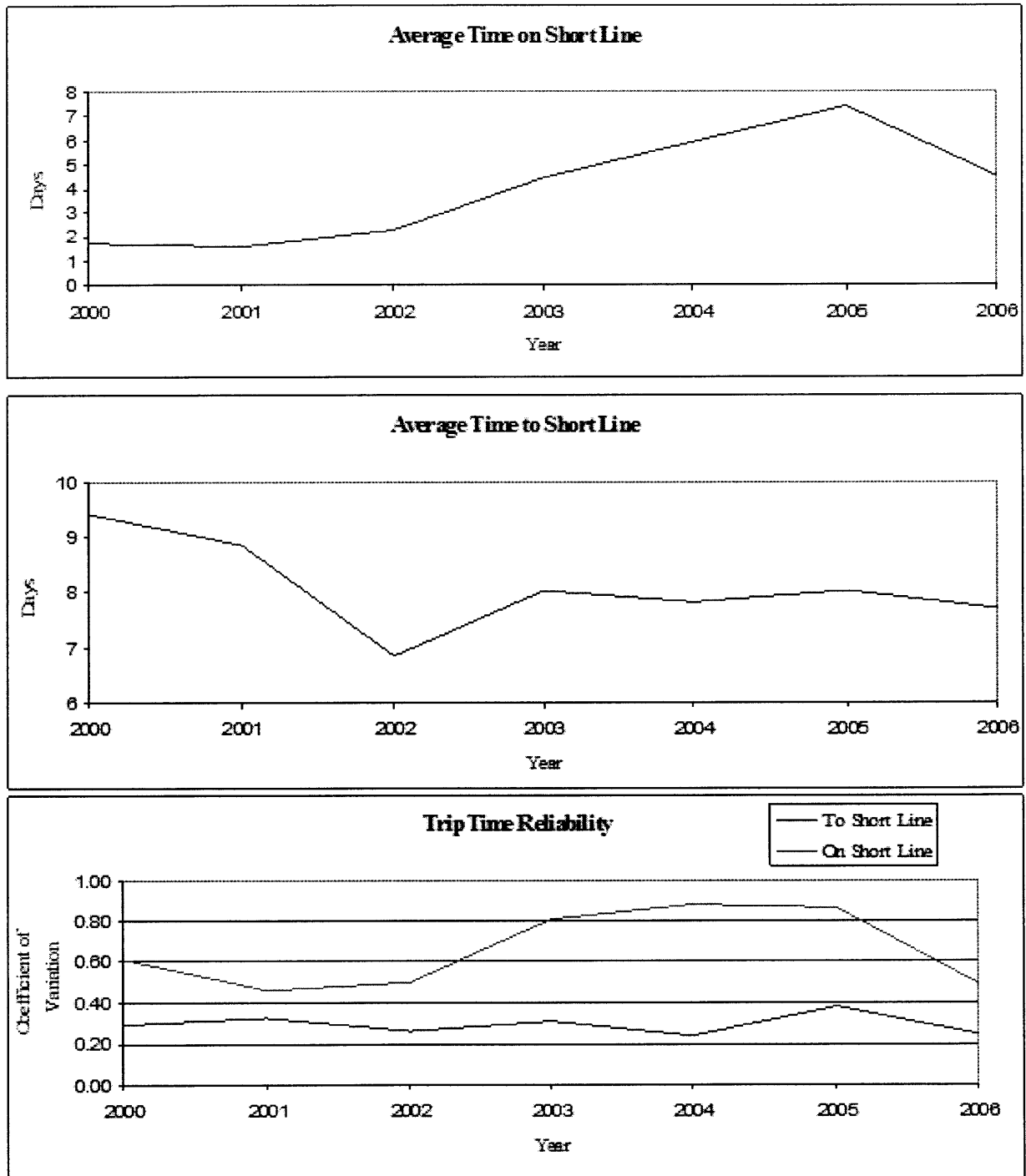
The data from Railroad "B" gives information on waybill date, date of interchange to Railroad "B" as the terminating short line, and date of interchange from Railroad "B" as the originating short line of the return move. Six different lanes are present in the Railroad "B" data, with data from 2000 into 2006. Due to variations between lanes, the aggregate data from the railroad is inconclusive in showing any clear trend in transit times. Figure 4-10 on the next page shows the average trend in time spent on Railroad "B" for all six lanes.

**Figure 4-10. Average Time Spent by Cars on Railroad "B"**



The one consistent trend across the six lanes reported by Railroad "B" is that trip time reliability between waybill date and interchange to short line, measured by standard deviation divided by number of days in transit, is always below 0.40. The lower the trip time reliability index (or coefficient of variation, defined in Section 3.3.3), the less variance there is in the move. The coefficient of variation of the time spent on Railroad "B" is always below 1.00, but is consistently above the coefficient of variation of the overall trip, indicating higher variability. Examples of the results obtainable from one of the six lanes are shown on the next page in Figure 4-11.

Figure 4-11. Railroad "B" Results for Sample Lane



## 5 Analysis of Results

In each subsection of Section 5, the results are presented in the same order as the data in Section 4 was presented. This facilitates easy comparison of the findings in the Results chapter and the discussion in this Analysis chapter.

### 5.1 Results from MIT Study

In discussing the MIT study, one of the points is that despite quicker point-to-point competition from trucking, certain short hauls have thrived. As presented in Section 4.1, eight of the lanes have equivalent road mileage (as measured by Google Maps) of less than 250 miles, and a total of sixteen are less than 500 miles. There are another eleven lanes between 500 and 750 miles, meaning more than two-thirds of the lanes studied are less than 750 miles. The average unweighted distance for all moves in the main data set is 715 miles; this is similar to the average of 796 miles found in 1990-1991<sup>22</sup>. It must be noted, though, that the 715 miles as measured are road miles, and the miles measured in 1990-1991 are track miles.

Another note on the time from release to general place is that while the weighted average is 8.3 days per car from customer release to general place, the unweighted average between the same events is 9.3 days. The significance of this data, presented in Section 4.1, is that high-volume moves appear to take less time than low-volume moves, which may indicate a certain railroad priority toward heavier or more regular shippers.

The weighted average, as noted, favors higher-volume shippers. Thus it might be compared with the 7.2-day average for high-volume shippers in 1990-1991, as studied in the 1995 Kwon et al. report, showing a moderate increase in overall trip time. The unweighted 9.3-day average may be compared with the 8.8-day average trip time from that same report, or with

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<sup>22</sup> [Kwon et al., 1995]

the 9.8-day average for interline shipments, showing no notable increase or decrease. Since all of the lanes in the MIT study involve short lines either originating or terminating loads, they are all interline loads. In general, measures related to trip time reliability show slightly greater unreliability than in 1990-1991, and trip times have risen somewhat.

Another significant result is that while shipping time is clearly positively related to distance, average car speed is also positively related to distance. As described by Equation 4.1, cars tend to travel an average of 3.1 MPH faster per 1,000 miles traveled. This is because cars traveling longer distances spend more time than cars traveling shorter distances in motion, as opposed to being stopped in yards or in interchange.

The result of the AECS (average equivalent car speed) equation is in spite of the increased number of yards cars may visit on longer trips. It is an effect of certain constants among all 39 lanes: all loads experience some origination delay (from release to pickup) and termination delay (from constructive to actual place), and all pass through at least one yard and one interchange. These delays are thus a larger fraction of total trip time on shorter moves.

With the above trend noted, the analysis of haul time versus road distance shows that cars move between shipper and customer at a weighted average of 2.4 road miles per hour (RMPH) and an unweighted average of 3.3 RMPH. Considering that truckers may drive a maximum of 11 in 21 hours<sup>23</sup>, this translates roughly to a truck speed of 4.6 MPH (weighted) or 6.3 MPH (unweighted), either of which is clearly a very low speed. Time-sensitive loads such as perishable items are clearly at a disadvantage on the railroad network, with an average speed approximately 1/10 of the Interstate highway speed limits (generally 55-75 MPH).

On average, it takes train cars just over half a day from destination arrival to constructive place. This is not unreasonably long, although there is room for improvement. The more

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<sup>23</sup> [FMCSA, 2005]



interesting statistic is the weighted average of 2.8 days between constructive and actual place, or the unweighted average of 3.5 days. With a standard deviation above 3 days, there is a high degree of variability between when a car is first offered to a customer and when it is actually taken by the customer. This can contribute to the variability of overall cycle time, and is a factor in the time from release to general place (since actual place is used when constructive place is not given).

Even when constructive placement data is not available, the time between the penultimate data point and actual place is still significantly large. On two lanes, the times between the last reported arrival and the reported actual place are 78 and 48.5 hours, respectively. A third lane, with a heavy volume of 403 cars reported in the 90-day study window, exhibits an average of 157 hours (over 6½ days) between the last reported arrival and reported actual place.

As noted in Section 4.1, the time from last Class I yard to arrival at or near the destination on a terminating short line is a measure of how long a short line takes to receive cars in junction and transport them to their destinations. There is an approximate 2½-day journey with 2-day standard deviation for cars to complete what is essentially the last leg of their haul.

With the results from the prior paragraph should be the caveat that not all railroads report events at the same time. This phenomenon is noted in the methodology and is important here, as the discrepancies between the time reported by the Class I railroad and the short line are as high as three hours in the main data set. This means that this final leg trip time may be even longer than the determined average, though not too significantly.

One final figure available from the data summary in Table 4-3 is the coefficient of variation, as defined in Section 3.3.3. In the context of this data, it allows the variation of the

total haul from shipper to customer to be compared to the variation of the time taken on various segments of that haul.

As found in Section 4.1, the weighted average coefficient of variation is 0.38 for the overall haul, and it is 0.88 for time from destination arrival to delivery<sup>24</sup>. This means that there is considerably more variation per day along the terminating line than from the origin to receipt by the terminating line. However, since time on the terminating line is relatively short compared to the overall haul (13 hours versus 175 hours), most of the variation in the total trip is introduced before loads reach the terminating line. Similar comparisons of the coefficient of variation may be made to other parts of the total haul, or to the same statistic gathered from other train movement samples, provided the context of relative haul time is considered.

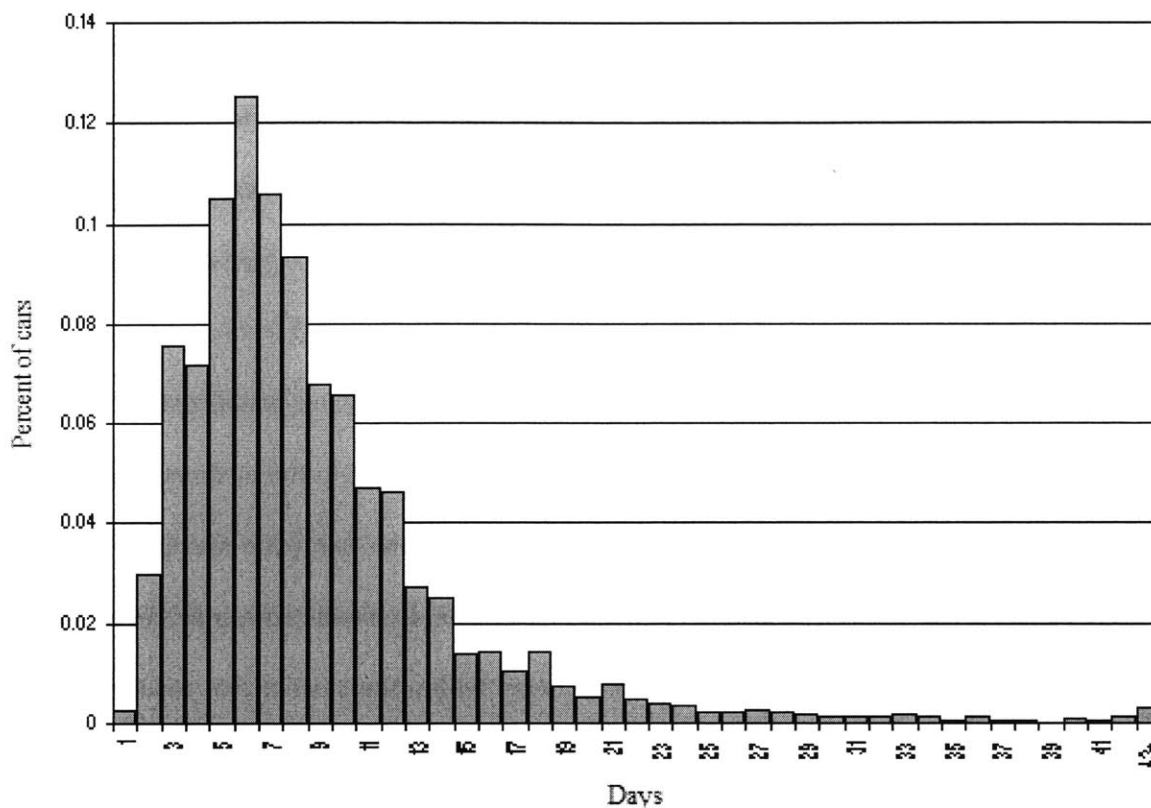
The ranges in the data are also telling. From customer release to general place, lanes in the main data sample experience average haul times anywhere from 70 to 614 hours, or between 3 and nearly 26 days. On one particular cross-country move, this means that the customer must wait an average of nearly a month to receive a shipped load. While such long average haul times are rare, as evidenced by the overall 8.3 day haul time average, they indicate that there is room to improve the level of service being offered.

Figure 5-1 on the next page shows the distribution of time from release to general place for all cars included in the sample, demonstrating the approximate 8 day average as well as the extremely long data tail toward 43-day shipment times and beyond. The fact that the mean time from customer release to general place is over 8 days and the median is under 7 days can be explained by that long tail.

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<sup>24</sup> Delivery is defined as constructive place for the purpose of this analysis.

**Figure 5-1. Distribution of Times from Release to General Place, Main Data Set**



The 90th percentile day is the fifteenth day after release – within 15 days of release, 90% of cars will have arrived at general place. In the same vein, the 95th percentile day is the twentieth day after release, meaning that most customers can expect shipments to arrive within 2-3 weeks. Some, but not all, of the five percent of cars arriving after the 20<sup>th</sup> day, especially the few taking more than a month to arrive, have experienced bad orders, customer overload (requiring a long time between constructive place and actual place), or some other special circumstance.

As another measure of trip time reliability, the weighted average maximum percentage of cars to arrive within any two day window is 44.7%, and the unweighted average is 49.8%. These

percentages are comparable to the 48.6% as measured in 1990-1991<sup>25</sup>, and do not show a significant decline in reliability.

Some lanes deviate notably from these average 2-day percentages. One 569-move lane has a 2-day percentage of 23.7% (arriving between 7 and 9 days), consistent with its observed standard deviation of seven and a half days and high coefficient of variation of .606. A comparatively reliable 249-move lane has a 2-day percentage of 68.3% (arriving between 5 and 7 days), and a 3-day percentage of 88.4% (from 5 to 8 days).

Another significantly large range is between constructive and actual place, where cars may take an average of between 14 and 252 hours to be delivered to the customer. This means that the particular short line involved can expect to hold the car over ten days before the customer accepts the offered shipment. While this may actually be the customer's choice instead of the fault of the railroad, it represents a large delay within the system that reduces car cycle time and thus reduces the efficiency of the national railroad network.

For the most part, the majority of the variation in trip times on any haul could be attributed to time between constructive and actual place. Between origination and constructive place, most of the variation occurs on the main haul, defined as the Class I railroad taking cars the longest distance. However, the coefficient of variation on the main segments is consistently below 0.40, meaning that the contribution of the main haul to overall trip time variation is an effect of the distance the cargo is being hauled, and not due to events causing abnormal variation during the main haul.

On one line, most of the reported times from destination arrival to actual place are quite small at three minutes, but there are a few outliers at times such as 11.3 hours, 58 hours, and 117.55 hours. This indicates a general good performance on this terminating short line, but

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<sup>25</sup> [Kwon et al., 1995]

occasional factors may delay shipments, sometimes significantly. Most likely either the shipper is asking to delay an occasional shipment, or the short line occasionally is not able to immediately place the car at the shipper.

Upon being broken down into segments, some of the individual lanes exhibit interesting characteristics. On one small move (ten cars reported), the originating railroad consistently takes approximately 6, 24, or 75 hours to deliver cars from shipper release to Class I junction. This indirectly measures the service provided by that short line, as a car ready to be picked up may wait as long as three days before the short line runs a train by that particular shipper. Another originating railroad takes an average of 29.3 hours to deliver cars from shipper release to Class I junction, but some of those short-distance moves take up to ten days. This points to a significant recurring problem on that short line, whether the fault of the railroad or the shipper (or neither).

Among terminating railroads on individual lanes, one showed an average of nearly nine days between junction receipt from the line haul Class I railroad and delivery to the customer at actual place. Since constructive place was not reported for this move, it is unknown how many of those nine days are due to the customer delaying shipment pickup. However, not only is that average far longer than for any other terminating railroad in the sample, but also the maximum reported time on short line of 38 days is egregiously long.

#### 5.1.1 MIT Study Special Cases

The two lanes analyzed in the pilot sample provided by RaiLinc yield different useful information. Depending on the characteristics of the data of a particular lane provided by RaiLinc, it may be analyzed in a manner similar to one of the two lanes below, or there may be other useful analyses to perform.

#### 5.1.1.1 Results from Lane 1

Lane 1 is analyzed with particular attention to the events taking place on the terminating short line, measuring the times between receipt from the Class I line haul railroad, destination arrival, constructive place, and actual place. All of the junction receipt times are between 11:30 AM and 5:33 PM, indicating a fair amount of consistency in when the short line runs its trains. Most of the line haul times (time spent on the Class I) are between 4 and 5 days, with the longest just over 7 days; there does not appear to be a significant or consistent pattern of problems in the line haul.

Most of the times from junction receipt to destination arrival are on the order of three hours, but one train took 8 hours and another took 14 hours. The three longest train times (including these two) all occur in January, possibly indicating delays due to colder weather, although this short line is located in the southern United States. It is also possible that there was a reporting practice inconsistency in January, as the reported times between destination arrival and constructive place are the shortest when the receipt to arrival times are longest.

All in all, time from junction receipt to constructive place is very consistent, at 16.3 hours with a standard deviation of just 1.5 hours. However, as mentioned in Section 4.1.1.1, one train takes over 62 hours between destination arrival and constructive place. This outlier also happens to be the only train to have received cars in junction on a Friday. The president of this railroad explained that the cars arrived at their destination at 5 PM on Friday, and thus could not be delivered that entire weekend. Finally, Monday morning, the cars could be constructively placed; one car was accepted for actual place about 3 hours later, and the other two were accepted 9 hours later.

Customer acceptance of loads delivered in constructive place is a significant issue on this short line. The time from constructive to actual place is 4½ days, with a standard deviation of 5 days. As noticed in some lanes from the main data set, there is a lot of time spent between the railroad being ready to deliver cars and the customer being ready to accept them. The Lane 1 data shows a possible seasonal or else simply periodic variation, as the highest times to actual place occur in January, with lower times in February and March. This could indicate a temporary shipper issue, or could be a systematic variation due to production ebbs and flows.

Another issue is the time between delivery by the Class I railroad and acceptance by the short line. Most of the junction times greater than one day occur when cars are delivered for junction on Saturday and Sunday, probably reflecting less frequent weekend service offered by the short line. The fastest junction times occur on Monday and Wednesday, again indicating when short line service may be most frequent or the short line most responsive.

#### 5.1.1.2 Results from Lane 2

Lane 2 data exhibits a lot of interesting railroad practices, and yields many thorough analyses. One practice of note is that the Class I line haul carrier appears to be delaying car pickup from the originating short line until there are more cars available. This might be an effect of when trains that are able to pick up the shipments run by the junction with the originating short line, or it might be a conscious practice to minimize the number of times a train must stop to add cars. The effect of it is that, in the 36 cars studied, three are delayed by about a day in junction, which skews the times measured from junction delivery to junction receipt and ultimately train departure from interchange. It may be more efficient for the Class I railroad to

consolidate cars in such a manner, but from the customer perspective, shipments are taking longer.

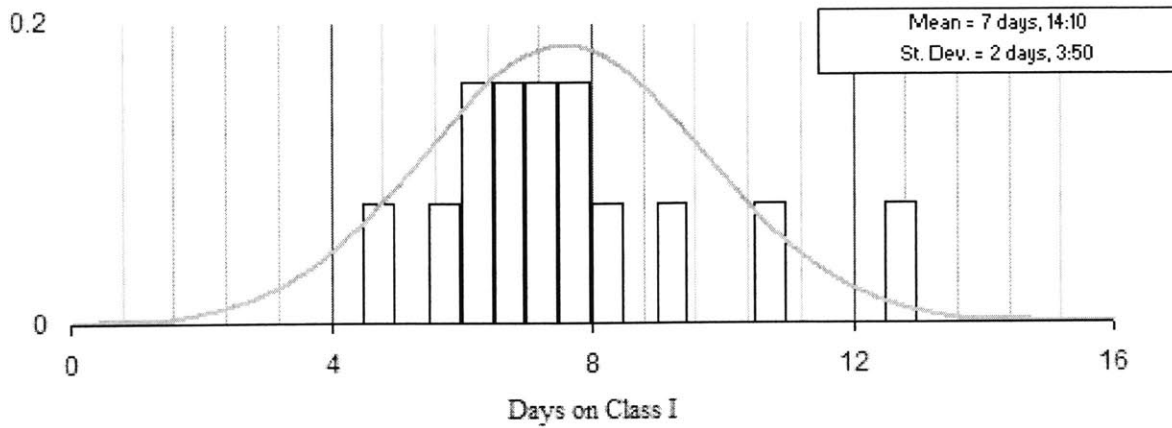
Another practice exposed by the detailed data available is routing inconsistency. A total of ten cars in three separate shipments each pass through a unique yard that none of the other cars in the sample visit, while five cars miss one “usual” yard and seven cars miss another. While in most of these cases, the appearance of missing the yards may be due to inconsistent event reporting, it is clear from the cars that visit unique yards that there are routing inconsistencies within this lane. Some cars may miss a connection at one yard and have to be routed through a different yard in order to avoid waiting several days for pickup, or may be allotted to the wrong train and have to be reassigned at the next yard. Other cars may be routed on “express” trains that skip yards, to try and make up some time from the overall haul.

From a trip time perspective, inconsistent routing may represent inefficient routing that ultimately increases overall haul time. Among the possible causes are missed connections at yards, other train delays, or misroutings. However, it may represent an occasional capacity issue along the usual route, and would thus be a symptom of a different problem. Also, from a cost perspective, it may represent the occasional availability of a cheaper routing option.

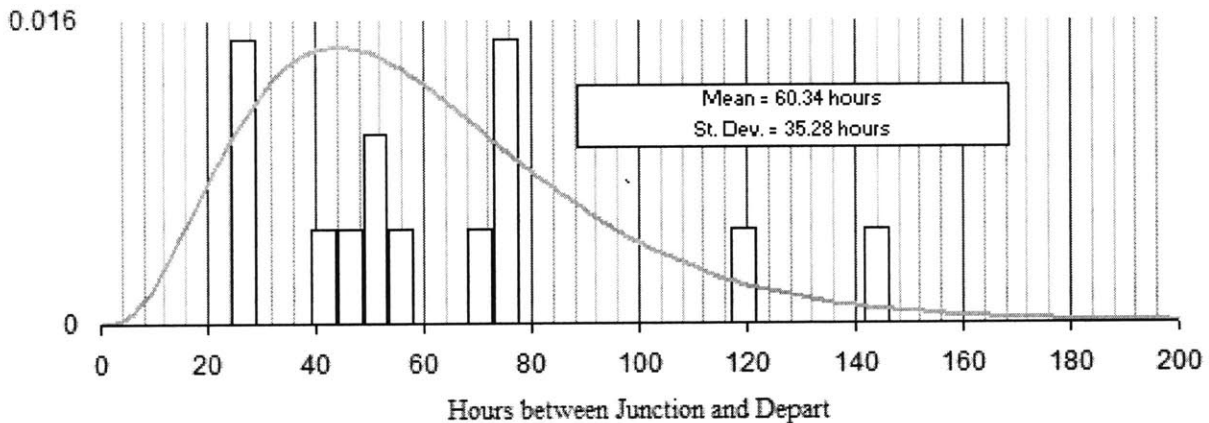
Despite the occasional variability in routing patterns, most of the variability introduced in the Class I line haul stems from the first practice noted, i.e. the long time taken between receiving cars in junction from the originating short line, and then departing from that junction. See Figures 5-2 and 5-3 on the next page for a comparison of the variability in haul time and junction-to-depart time.



**Figure 5-2. Class I Haul Time Performance on Lane 2**



**Figure 5-3. Junction to Depart Time Performance on Lane 2**



The bars on the above figures represent actual data points from Lane 2. The smooth lines drawn, based on the given mean and standard deviation, are an approximation of what the overall trip time distribution may look like, given more data<sup>26</sup>. However, in Figure 5-3, there appear to be peaks near 1, 2, 3, 5, and 6 days. More data might show a clear periodic daily performance, wherein the time spent in interchange depends on when the next train arrives that can take the

<sup>26</sup>Formulas are not given because there are too few data points to construct reliable distributions.

load. In this case, the smooth line as drawn is only a very rough approximation, and actual performance would better be modeled in terms of days in interchange, not hours.

From Figures 5-2 and 5-3, the coefficient of variation for the Class I line haul is .285, while that of the time from junction with to departing from the originating short line is .585. The blue lines represent an approximation of what the functions for these two measurements would look like with enough data points. Haul time performance appears to be roughly normally distributed, while due to its long tail (influenced by the aforementioned practice of delaying cars in junction), the time from junction to depart appears to be roughly exponentially distributed.

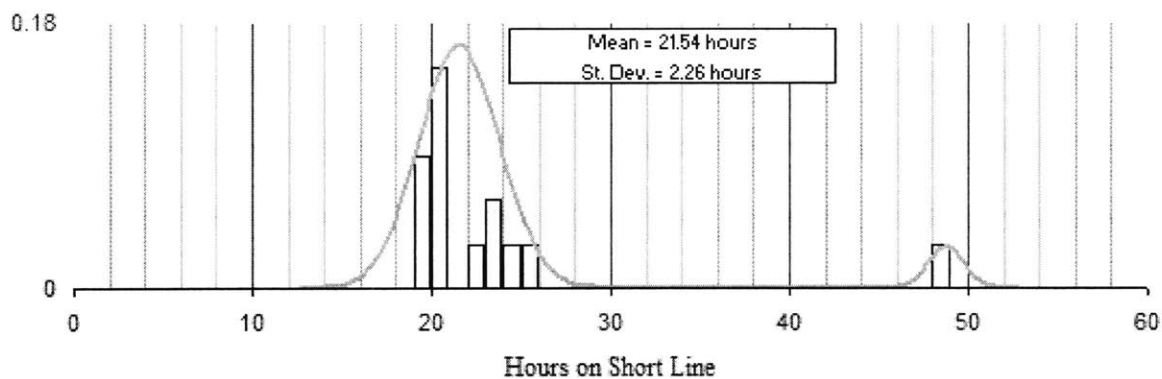
In a normal distribution, 68.26% of times will fall within one standard deviation, and 95.44% will fall within two. This means that to a 95% degree of certainty and with a normal approximation, the Class I line haul could only be expected to take between 3.2 and 11.9 days. Also, expected time from junction to depart would range from 0 to 130 hours. Thus there is a large amount of variability introduced in the Class I section of the haul.

While yard times along the route are variable, they do not appear to be highly correlated, because the data show that cars tend to arrive in a consistent amount of time. If a car spends an extra day in one yard, it may make it through the next yard somewhat faster than other cars, and if a car is misrouted at one yard, it may be expressed through the next yard to save time.

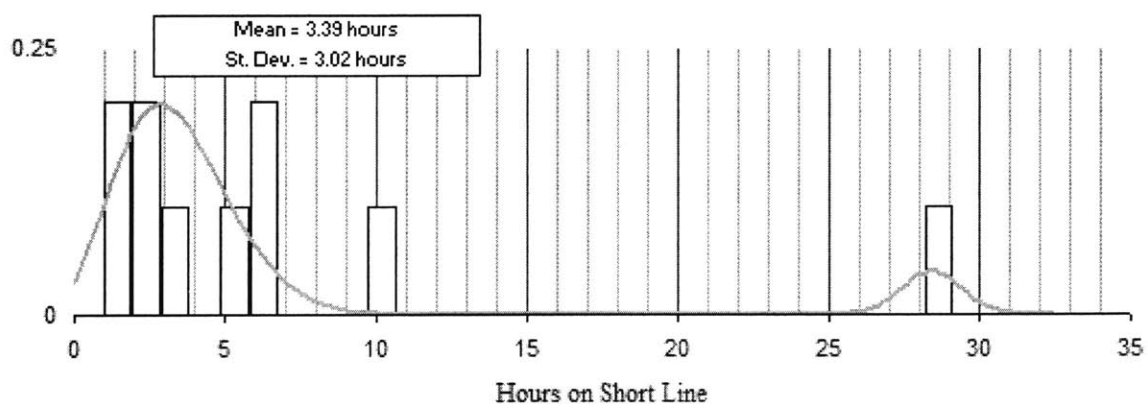
Yard times would be the subject of a separate study, as discussed in Section 6.2. It appears, though, that yard times do not contribute nearly as much to the variance in overall trip time as does the time from short line junction delivery to Class I interchange departure. Thus faster and more consistent pickup of cars received in junction appears to be one of the most immediately effective ways to improve level of service.

Figures 5-4 and 5-5 below illustrate the haul times on the originating and terminating short lines, with the same approximate distributions drawn in. Means and standard deviations shown are for the main peaks only. Ignoring the outliers in the short line segments of the haul, the variations of times are a lot shorter on those lines than on the main Class I haul, introducing hours instead of days into overall trip time variability.

**Figure 5-4. Originating Short Line Performance, Lane 2**



**Figure 5-5. Terminating Short Line Performance, Lane 2**



As noted, there are two outliers - one each on the originating and terminating short lines. Similar to the case with Lane 1, the originating "outlier" can be explained by the fact that the car

was left for pickup on a Friday, and trains do not pick up on Saturdays. It is still relevant, as the customer can expect shipments to take an extra day approximately one-seventh of the time. The terminating outlier is probably attributable to a one-time issue with the customer, since time from receipt to constructive place is only 1 hour. The day of week (Monday) is not the reason for that delay, because two cars delivered at the same time of day on a different Monday are actively placed within two hours.

## 5.2 Results from Railroad “A”

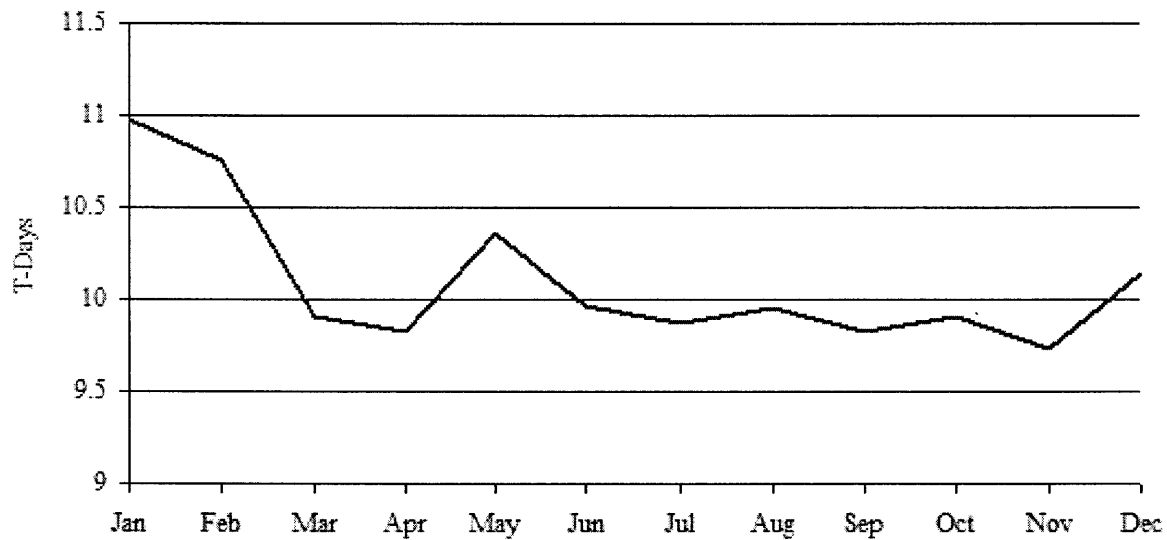
After an initial drop from 2000 to 2001, the number of T-Days (days in transit) for the particular Class I railroad connecting to Railroad “A” rose steadily through 2005. Since a large number of cars (2,500 to 4,800) arrive yearly at Railroad “A” via this Class I railroad, such a rise is significant. To support the idea that it does not merely indicate a geographical shift in shippers, the measure of average T-Days for all shipments coming from Illinois was 7.3 days in 2001 and 7.8 days in 2002, rising steadily to 10.4 days in 2005.

Because car routes have not changed dramatically over the time period studied, the increase in time is occurring along the same routes and at the same yards. Increased congestion on trunk lines and in yards may account for the added delays, as more line congestion would slow trains down and more yard congestion could delay incoming cars from being sorted and placed on the proper outgoing trains.

Another significant trend is shown in the monthly variation of shipment times, shown below in Figure 5-6. The peak in January, supported by rises in December and February, represents factors due to inclement winter weather, such as snowdrifts or frost heaves. Because

short line "A" is located in the Northeast, and most of its customers lie in the northern half of the United States, winter weather is a reasonable explanation of this peak.

**Figure 5-6. Transit Times to Railroad "A" by Month, 2000-2005**



As mentioned above, the overall trend on shipments to Railroad "A" has been an increase in shipping times from 2001 to 2005, but there was also a significant increase in shipping volume from 2001-2002. The series of volume-shipping time graphs from 2000 to 2005 shows that among the heaviest origination states (more than 400 cars per year shipped to Railroad "A"), none requires more than 16 days to ship, which is also true of moderate origination states (100 to 400 cars shipped yearly to Railroad "A") except for Texas. This may indicate that reliably high-traffic customers may receive better treatment by the originating and connecting railroads than low-traffic occasional customers.

The graphs also demonstrate that long shipping times one year tend to remain long through the years, while states with short shipping times tend to retain shorter shipping time. Obviously, some of this phenomenon is geographical, as states closer to the Northeast will tend

to exhibit shorter shipping times, but the major origination state of Illinois, despite being several hundred miles from Railroad “A,” also retains a short shipping time, while the shipping time from closer Pennsylvania consistently tends to be slightly longer than among other states in the region. The explanation for this consistent trend probably lies in the practices of the originating and connecting railroads in each state, including the potential for Class I railroads to offer faster or more frequent service along certain lines (such as those from Chicago eastward) than others (such as those heading north-south through the mountains).

### 5.3 Results from Railroad “B”

In looking at the average trip time over six years for the six moves reported by Railroad “B,” the one consistent trend is that there is more variability per day in time spent on the short line versus time taken to arrive at it. This variability, measured by the coefficient of variation, indicates that there is greater relative unreliability on the part of the short line Railroad “B,” though this may be influenced by unreliability in customer dwell time. The customer dwell time, or how long cars spend with the customer during storage, unloading, and sometimes reloading, is included in the time between junction receipt of the incoming move by short line “B,” and delivery to junction of the return move.

It is worth noting that unlike in the examples from the main data set, the main haul is not always responsible for most of the variability in the total haul. For the two of the six lanes in the Railroad “B” data set that have times on the short line lasting for weeks, the variability of the time on short line dominates the overall trip time unreliability. For the other four lanes, with times on the short line that last only days, the standard deviations of the time taken to short line and time spent on short line are approximately equal.

There is also an inconsistent trend present in Railroad “B” data, and that is the yearly trend of trip times for each of the six moves. Two of the six moves show a general increase in time from release to Railroad “B” junction from 2000-2006, while two of the moves show a general decrease in time. One move shows no clear trend, while the final move shows an increase in time until 2004, followed by improvement!

No conclusion can be drawn as to any general shipping trend, but it is worth noting that at least in the short term, the shipping time relative to a particular lane is independent of shipping times relative to other lanes. The ramification of this is that increases in shipping time on individual lanes can be dealt with individually, while decreases on individual lanes may merit closer examination of good shipping practices on that lane.

In analyzing the time on short line for the six moves, there is a wide discrepancy between them. Four of the moves have low average times (generally under one week) between receiving a car and delivering it back to the connecting Class I railroad. Two of the moves, however, have average times on short line of four weeks and 5-9 weeks, respectively. These moves involve private tank cars, and thus it is up to the owners when to release or hold the cars. The cars may be held for weeks by the customer, and thus may skew the perception of high car cycle times.

The overall trend for time on short line is a sharp increase from 2000-2001, followed by a general decrease from then until 2006. Again, this is a lane-specific measure; time on short line for two customers generally increases from 2000-2006, while for two other customers it generally decreases. One lane shows no consistent trend, while another shows a peak in 2002 followed by somewhat of a decrease.

The group funding the MIT study cited the span during which a customer is holding a car as one of the problems in reducing car cycle time. As with the measure of time to short line, the

ramification of the data from time spent on Railroad “B” is that each lane’s trends should be analyzed independently for good and bad delivery and customer practices. The ability to reduce overall customer holding time seems to lie in working with each customer individually.

One measure obtainable from the Railroad “B” data that cannot be determined from the other data sets is car cycle time, because only this data includes the time cars spend with the customer. The half cycle time is thus the time from waybill date (the assumed day of pickup from the shipper) to short line “B” junction delivery to the Class I railroad. While this half-cycle time measurement is imperfect, it does provide a measure of how many times a car may be used per month or per year, a key measure to railroad officials who are looking to maximize equipment utilization.

Excluding the two lanes that utilize privately owned cars, the average car half-cycle time from 2000 into 2005 is 15.4 days. Given the approximate loaded/unloaded ratio of 3:2<sup>27</sup>, the Railroad “B” data signifies that across the railroad network, cars spend just under a month on average between picking up loads. This points to a clear need and opportunity for improvement.

#### 5.4 Good and Bad Practices

One of the aims of the research underlying this thesis is to examine good and bad practices in the railroad industry. In the context of this thesis, the identified practices can help demonstrate ways to improve level of service.

Included in the data presented by Railroad “A” is an example of a good customer practice. One particular movement on Railroad “A” involves a steel mill shipping steel beams to its customer. This happens to be a short-distance move, but is particularly suited for railroads because by spending several days in a sealed railroad container, the steel has sufficient time to

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<sup>27</sup> [AAR, 2004]



cool without being exposed to elements. The same trip by truck would not take long enough to cool the steel, requiring a separate warehouse for storage, and the steel could be exposed to rusting while in that warehouse.

As an example of a bad practice, one of the 39 lanes in the main study underlying this thesis has a standard deviation of 227 hours from release to actual place. While much of this variability is due to the customer's determination of when to accept shipment, it still means that there is a 37-day window within which only 95% of shipments can be expected to arrive at the customer. In terms of equipment utilization, it would seem advisable to prompt the customer to accept cars not only more quickly, but with more regularity as well.

In another bad practice, some lanes do not have sensible or consistent routings. One shipping lane has a length of 735 road miles, but some cars in that lane travel from Arkansas to Nebraska and back, 680 road miles each way. Another car in that lane was routed up to Chicago and back. Thus the total distance of the move is sometimes tripled due to a bad routing, and the overall trip time increases due to unnecessary time spent in extra yards having cars switched between trains.



## 6 Summary, Conclusions, and Recommendations

As stated in the introduction, the purpose of this thesis is to analyze recent data from freight railroad lanes across the United States to determine details of the level of service being provided. The level of service is measured by trip time and trip time reliability, and in turn, trip time reliability is measured by standard deviation, coefficient of variation (defined in Section 3.3.3), and 2-day percentage (defined in Section 2.2.1) pertaining to each lane.

From the data gathered in this thesis, the parties involved in commissioning the MIT study hope to determine where there are problems in the level of service being offered rail shippers and customers. Initial data is analyzed from two short line railroads and from two lanes provided prior to the main data set. In the main data set there are 39 lanes analyzed for measures of trip time and trip time reliability.

The results presented in this thesis have another important ramification for the railroad industry. By examining where cars are experiencing the greatest delays, or identifying chronic problems with bad car routings, railroad personnel can work to improve car utilization by reducing cycle time and thus allowing more throughput across the rail network without increasing the number of cars on that network.

### 6.1 Conclusions on Rail Level of Service

The major conclusion from the main MIT study is that shipping times have increased moderately since the available prior data from 1977 and 1990-1991. In addition, transit times to some short lines are much longer than the observed weighted average of 8.3 days, as evidenced by the overall average standard deviation of 4.3 days. For example, the data sets from Railroads

“A” and “B” demonstrate average shipping times on the order of 10-12 days to the short lines, not even including time to destination arrival or constructive place.

The 8.3-day weighted average trip time from the main data set appears to have degraded since the 7.2-day average trip time from 1991<sup>28</sup>. However, the 9.3-day unweighted average is about the same as 8.8-day average for general merchandise and the 9.8-day interline general merchandise average. The weighted average is a better reflection of what an average moderate-volume shipper might expect, as the unweighted average is skewed by small-volume lanes with high average trip times.

As for trip time reliability, the average standard deviation of 4.3 days reflects a significant degree of unreliability in that trip time. The range of average lane trip times is from 2.9 days to 25.6 days, demonstrating that while some lanes exhibit very good performance, the trip time performances of other lanes are very bad. The range of standard deviations from 1.2 days to 9.5 days shows that some lanes exhibit very consistent performance, while others are very inconsistent. This is supported by coefficients of variation that range from .16 to .71. If, on average, customers can only expect shipments to arrive within an 17-day window, and on at least one line that window is as wide as nearly 38 days, the level of service is low enough that truck competition may erode the position of railroads in the freight marketplace.

The measurement of trip time reliability in terms of 2-day percentage shows a slight degradation from the 48.6% reported from 1991 data<sup>28</sup>. The average per-lane 2-day percentage across the main data set is 44.7% weighted by lane volume and 49.8% unweighted, and ranges from 17.4% to 85.7%. Again, this range reflects that certain lanes are highly reliable in when loads will arrive, while others are highly unreliable. The sources of trip time unreliability are the same sources as those of long trip times: there is a lot of uncertainty in when cars will be picked

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<sup>28</sup> [Kwon et al., 1995]

up from the shipper or received by the customer, and there is similarly high uncertainty in how long cars will be in yards or waiting in junctions before leaving on a train.

What the data also show is that most of the trip time is attributable to events during the Class I line haul and to interactions with the shipper and customer. Delayed pickup of cars released by the shipper can increase haul time, while one of the biggest contributors to trip time and trip time unreliability is delayed acceptance of cars ready to be delivered to the customer. During the Class I line haul, trains may move at a decent speed (300 miles in well under a day, as shown in Figure 4-9), but then cars will be delayed in yards for hours or even days.

The trends for yearly data suggest that practices on individual lanes may be responsible for improvements or diminishments in level of service. For example, the multiyear data for Railroad “A” demonstrates a consistent lengthening of shipping time on the connecting Class I railroad, which may be due to that Class I railroad’s health or operating practices or may reflect a more systemic problem. However, within the multiyear data for Railroad “B,” some lanes show improvement in both trip time and trip time reliability from 2000-2005, while others show diminishment in both areas.

There is also much significance to when cars are delivered as to the level of service offered. Since many short lines do not run service every day, cars delivered for interchange on an off day will have to wait at least an extra day before they can be brought to the customer. At the extreme, railroads that do not offer weekend service may delay cars received on Friday until the following Monday. This can also affect originating short lines, who may have to wait one or two days between the time a load is released by the shipper and when the short line is able to retrieve it. Better communication between shippers, customers, short lines, and Class I railroads can reduce the number of times these situations occur.

As noticed in the analysis of the data set from Railroad “A,” the month of the year can also affect deliveries. Trains that run through the northern part of the United States may be delayed by winter weather events such as blizzards or frost heaves, and the resulting spring may bring mudslides and washouts. The effect of winter weather may add a day or two to the overall trip time, which given the weighted average trip time of 8.3 days is highly significant.

#### 6.1.1 Improving Interchange Time

One clear area for improvement is interchange time, where the problems are twofold. Firstly, as exhibited in the two pilot lanes submitted prior to the main data set, cars interchanged to a terminating short line on the wrong day may experience days of delay before they can be delivered to the customer. Secondly, as exhibited by Lane 2 among those pilot lanes, there can be significant delay in car pickup by the Class I railroad from the originating short line.

Short lines cannot be expected to run trains every day, unless they have a consistent high volume of traffic. Through communication with the customers on the short line, it may be possible to standardize commodity delivery days and times, or at the very least develop an understanding of what days and what times trains will be running. The short line schedule must balance those customers’ needs with the limited flexibility of the Class I railroad to deliver cars for junction on different days and at different times.

The other area for improvement in interchange reliability is from the originating short line to the Class I railroad. Similar suggestions work for both originating and terminating short lines; by working with the various shippers located on the short lines, pickup of cars can be consolidated to certain times on certain days, minimizing the amount of times cars sit idle on sidings. Again, coordinating the short line schedules to the schedules of the connecting Class I

railroads allows prompt interchange with the correct train without waiting at the interchange yard for days.

Where feasible, ending the observed practice of Class I railroads delaying pickup of cars in interchange would improve interchange time and thus reduce overall car cycle time. As observed on Lane 2 (see Figure 5-3), three cars that originated between 1/4/06 and 2/6/06 appeared to have been delayed by a day to be consolidated with other cars, while other cars experienced delays between junction delivery and train departure of as long as five days. Accepting cars on each relevant train that passes the interchange yard can reduce by a day or more the trip times for some cars, though it may incur additional cost to the Class I railroad.

## 6.2 Recommendations for Extensions of Research

Certain additional analyses may be performed on the data available for the MIT study, as provided by RaiLinc. For example, one could study the mean times and standard deviations of train trips, as opposed to car trips. Such a determination would require the cars in each data set to be grouped by the trains they followed, and then regrouped as a different segment of the trip was studied.

Another possible study from this data is yard time analysis. The more consistent the routing of cars in each lane, the more consistently a yard appears in the data, enabling such analysis. Finding several different lanes that involve the same yard will prevent the data from being skewed toward a particular commodity or handling railroad.

Analysis of the two lanes in the initial pilot data included a sample of a yard analysis, demonstrating that it is possible given more time and perhaps more data to do a more thorough job. The limitations upon the findings from that data are that there are not enough data points to

draw any thorough conclusions. As an example of such a research extension, one of those lanes sends 193 cars through a particular yard, and exhibits the expected distribution of most cars being handled within 24 hours, and a smaller secondary peak for cars being handled within 48 hours.

The actual net car speed from shipper to customer was not calculated, as the comparison of railroad car shipping times and truck shipping times is more relevant to the issue of railroad reliability. Net car speed data, which would ignore occasional misroutings or reroutings, would provide views of the general congestion of the railroad system and the state of the trackage.

As another research extension, more detailed analysis of the Class I section of the haul may yield interesting results on routing anomalies such as doubling back, and can expose more areas for improving trip time. In the data provided for the MIT study, yard short lines occasionally interrupt the Class I haul, and sometimes two Class I railroads handle cars between the origin and destination, factors that can be taken into account before performing a Class I analysis.

Another possible area for analysis is when a Class I railroad acts as the originating or terminating railroad. It only carries cars for a short distance while another Class I brings the car along the majority of the route, thus making it similar in function to a short line railroad. This analysis could compare car pickup and dropoff times on Class I and short line railroads performing similar functions.

Finally, longer-term trends in trip times and trip time variabilities cannot be gleaned from 90-day data. Over months or years of data, it would be possible to assess monthly ebbs and flows in trip times and train traffic, as performed in the analyses of Railroads "A" and "B." Continuation of the research performed in the MIT study is of interest to the group sponsoring



that study, as it can provide a continuing picture of trip time performance on the American railroad network.

### 6.3 Recommendations for New Research Areas

Based on the data available for this thesis, it appears that improving yard performance and working to decrease the amount of time cars spend with customers can both improve overall trip time performance. In addition, empty hauls have not been studied for this thesis, in part because there is less tendency to ship empty cars directly from customer back to shipper; this is generally only done for specialized cars or the highest-volume routes.

Future studies based on events reported from car locations can focus on yard performance, examining whether the probability of a car making its scheduled train has decreased since prior studies were published. Other results from studying yard performance are whether there is an expectation of longer yard times, or whether there are more bad orders or bad routings than in previous years.

Studies of empty car movements can also be done from RaiLinc data, although it may be difficult to specify lanes over which empty cars consistently move. An examination of empty car assignment and storage practices would be useful in aiding level of service and car utilization improvements. Studies of dedicated empty car lanes may also yield interesting best or worst practices as case studies.

Time on short line, especially the section thereof during which the customer is in possession of the car, can also be studied from RaiLinc data, by tracking certain cars for several months. From the limited Railroad “B” data, it appears that customer car possession may be a critical piece of car cycle time. Car identification is important for such a study, in order to

separate privately owned cars from railroad-owned cars and analyze any discrepancy in results for each.

## Appendix A: Formulas in Excel

The two preliminary lanes provided by RaiLinc and the data provided by Railroads “A” and “B” were all analyzed by hand, as was one of the 39 lanes in the main study. The other lanes from the main study were organized to have columns in the same order and format, and then formulas were applied to those columns. This appendix describes those Microsoft Excel formulas, with a detailed formula summary at the end of the appendix.

The first column represents the number of hours elapsed since the beginning of a move, defined as shipper release except for one lane on which shipper release was not reported; for the latter, the beginning of a move is defined as pull from shipper (for definition, see Table 3-1). The formula for this column has to take into account two inconsistencies: some movements are missing part of their reported events, and so may miss their beginning or ending, and also there is sometimes a blank event reported before shipper release.

Each of the trip time segment measurements is two columns wide. In the first column of each segment I keep track of time elapsed from the first event of interest to the second event of interest. Each formula has to be able to reset across both partial movements (as explained above) and movements wherein an event of interest is not present. In some formulas, I use a dummy value of 80,000 to represent a missing event of interest, such that the corresponding cell for the next event will reset upon reading the 80,000 in the prior cell.

Finally, in the second column for each segment measurement, I copy the number from the first column that represents the total time for the segment of interest. Within this formula, I account for erroneous measurements (such as the 80,000 mentioned above) that may appear in the first column by making sure the event of interest is actually reported in that row.

Figure A-1. Excel Formulas Used for Main Data Set

Formula for Time from Beginning of Event	=IF(I5="Z",,IF(I5="",IF(I4="Z",,F6-F5+24*(E6-E5)+M5),IF(I6="W",,F6-F5+24*(E6-E5)+M5)))
Formula for Time Between Events (W-Y)	=IF(I6="Y",M6+G6/60-P5,IF(I6="Z",80000,IF(I6="",IF(I5="Z",80000,IF(P5<1,P5,G6/60)),IF(P5<1,P5,G6/60))))
Formula for Recording Time Between Events (D-Z)	=IF(R6=0,"",IF(R6>1000,"",R6))
Formula for Recording Time on Short Line (Originating)	=IF(L6="[RR1]",IF(I6="W",E6+(F6+G6/60)/24,IF(I6="J",E6+(F6+G6/60)/24-X5,X5)),X5)

The above formulas are taken from one of the 38 data sets; they are similar for all 38. The sample formulas in the table are from row 6. Column E contains the date (year, month, day), column F contains the hour of the day, and column G contains the minutes. Column I contains the events reported, as described in Figure A-2 below (see Figure 3-1 for definitions of the events). Column L is the railroad's alphabetic identity, and for privacy purposes is represented in these sample formulas by [RR1].

Figure A-2. Definitions of Alphabetic Event Codes

W – Shipper Release	D – Destination Arrival
X – Pull from Shipper	Y – Constructive Place
J – Junction Delivery	Z – Actual Place
R – Junction Receipt	“” – denotes a nonreported or blank event

It is possible to construct the reported date and time differently than it was done for this thesis. Rather than separate date, hour, and minute into three separate columns, they may be recorded as a single time value in one column. This will result in more streamlined formulas, but the results of any analysis performed will be identical.

The formula for time from beginning of event is reported in Column M. It resets to zero after a reported actual place, and if a blank event is reported immediately after actual place, time will reset to zero after the blank event. These measures take care of partial movements that start

in the middle of the movement. Finally, if a shipper release is reported, time resets to zero as well.

The formula for time between events, in this case recorded in Column P, depends on the hours reported in Column M. At the beginning of each move, it records the minutes of the reported time as a fraction, and preserves that value throughout the move. Upon report of a constructive place, it adds the number of hours from the beginning of the move to the minutes from Column P above, and then subtracts the minutes of the time recorded at the constructive place. If actual place is then reported, the dummy value of 80,000 is used as a placeholder. Once a value greater than 1 is recorded in Column P, the move has finished, and will reset upon the beginning of the next move.

The formula for recording time between events, here recorded in Column S, is relatively simple. If an abnormally high value (such as the dummy value of 80,000) appears in the preceding column, it is discarded. Abnormally high or low values also appear when partial movement reporting “tricks” the formula into thinking two movements are part of the same one; for data sets in which negative values are reported, there is an additional provision to throw those out. Unless a correct value for the segment in question (here D-Z) is present in the adjacent column, this formula returns a blank cell, so that mean and standard deviation may be measured at the bottom of the column.

The formula for recording time on short line may be modified to return time on the main Class I shipper, or yard time, or time between any two events. In this case, it is recording the time on an originating short line. It thus resets upon shipper release, recording the minutes of the time of release as a fraction of an hour, and when the originating short line reports a junction delivery, the formula yields the time from release to delivery on the short line. The formula is

constructed to ignore junction delivery on other railroads, and simply copies the preceding cell as a default action.

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